MALARIA CONTROL HISTORY - WORLD WAR II

MILITARY MALARIA CONTROL EXPERIENCE IN THE CONTINENTAL UNITED STATES

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SYNOPTIC SUMMARY

The last "epidemic" wave of malaria in the United States before World War II occurred during the mid-thirties of this century. Following this episode, the reported incidence of the disease declined steadily. In 1941, it was the lowest since 1910 when the Registration Area was established. Another general rise shortly thereafter was predicted by some malariologists on the basis of the five- to seven-year periodicity in the outbreaks previously observed.

During the years just before the war, cases were reported with some regularity from the coastal sections of North and South Carolina, Georgia, Alabama, Mississippi, Louisiana, Texas, and the northern part of Florida. A few were notified from the flood plains of the upper Mississippi basin, but the more important areas of inland reporting were the fluvial environs of Tennessee, Kentucky, Arkansas, Mississippi, Louisiana, eastern Texas, and Oklahoma.

This history of recent endemicity and the expectation of a cyclic resurgence of epidemicity from 1941 to 1943 were of great importance to the U. S. Army Medical Department as it was planned, for various reasons, to locate many of the proposed training camps

in the South. It would have seriously impeded the war effort if military trainees contracted malaria in this area and required hospitalization in this country and overseas as a result.

To minimize this hazard, the responsible authorities in military establishments, with the advice and coordination of malaria control specialists in Service Command Headquarters and in the Surgeon General's Office, engaged in extensive malaria control operations on military property.

During the period from April 1941 through June 1945, over $11.5 millions of appropriated funds were expended through Service Commands for mosquito control[1] at posts, camps, stations, and other military reservations totalling 12,758,138 acres in extent. Slightly more than half of this money was spent for permanent anti-mosquito improvements, the balance for temporary measures such as larviciding and residual spray treatment.

The following is a summary of the accomplishments of this program: clearing or brushing, 203,501 acres; new ditching, 8,948,397 lineal feet; channel or ditch cleaning, 40,351,031 lineal feet; fill, 6,420,516 cubic yards; ditch lining installed, 1,400,308 lineal feet; water surface eliminated, 43,830 acres. Larviciding activities included the application of 5,782,703 gallons of diesel oil, 85,382 pounds of Paris green dust mixture, 435,485 gallons of other larvicides. About 125,257 gallons of 5 per cent DDT in

diesel oil were used in residual spraying of military premises during 1945. The labor required for the conduct of this work involved 11,876,195 civilian man-hours and 2,924,258 other man-hours, mainly from prisoners of war.

Service Command entomologists recommended allotments of funds for projects, maintained proper liaison with Medical Department representatives, assisted Post Engineers with the training of supervisors, foremen, and laborers for the execution of mosquito control measures, and made periodic inspections of work in progress or accomplished.

Developmental work for the improvement of equipment used in the dispersal of insecticides and larvicides was conducted in cooperation with the Engineer Board, Fort Belvoir, Virginia.

To supplement these measures, the U. S. Public Health Service through its specially activated Office of Malaria Control in War Areas assisted and coordinated State health department efforts in suppressing malaria vectors around cantonments and other areas of military importance.

From March 1942 to the end of fiscal 1946, the antimalaria accomplishments of the U. S. Public Health Service around military areas were as follows: clearing, 30,003 acres, and cleaning, 84,670,867 linear feet of ditches; the application of 5,692,181 gallons of oil and 583,991 pounds of Paris green in larviciding

829,275 acres; the construction of approximately 19,335,875 linear feet of drainage ditches, 90 per cent of them by hand labor, 5 per cent with dynamite, 3 per cent by heavy machinery, the other 2 per cent being lined or tiled ditches; the placement of mechanical and hydraulic fill amounting to 293,468 cubic yards; and the spraying of most of 798,322 pounds of DDT in 1,289,863 houses, a small amount of DDT being used for larviciding. The Federal cost of these activities amounted to about $31.7 millions. In addition to the actual anopheline control operations, this sum supported efforts to evaluate the control activities in terms of parasite prevalence and anopheline density; to conduct an anti-*Aedes aegypti* program; to train technical directors, inspectors, and work supervisors; to provide technologic assistance in solving operational problems; and to institute community educational programs.

Largely as the result of these combined military and civilian antimalaria efforts, the malaria admission rates of the Army in the continental United States were maintained during the war years at low and decreasing levels. This was in sharp contrast to the comparable military experience during and after World War I.

MILITARY MOBILIZATION IN POTENTIALLY MALARIOUS AREAS
OF THE UNITED STATES

The prescribed missions of troops stationed in the continental United States of America are (1) to protect the area and (2) to be trained for military duty at home and abroad. Malaria had been an impediment to military training in the southern United States during World War I.[2] It continued to be endemic in certain parts of this area as late as 1940. To prevent the disease from becoming an incapacitating risk to the fulfillment of the above objectives and to preclude the hazard of exporting military personnel with latent infections to become disease casualties abroad, large-scale antimalarial operations were undertaken from 1941 to 1946 on and near U. S. Army areas in the potentially malarious sections of the continental United States, mainly the southeast quadrant of the country. This region, where the climate allowed year-round outdoor operations, was selected by both the ground and air forces for the establishment of numerous military installations, mostly for training purposes. In 1942, there were 499 such facilities[3] in the 17 States[4] where it was believed that malaria might infect troops and thereby seriously hamper training programs. The ever-widening spread of war created an urgent demand for greater numbers of trained fighting men. In 1943, 90 additional military posts were opened, raising the total number in these States to 589.[5]

This figure remained virtually the same in 1944 (583),[6] but by 1945, as a result of the cessation of hostilities, decreased to 520.[7]

There is a direct correlation between these figures and the numbers of troops involved. In 1942, 2,261,675 men,[8] many of them from non-malarious areas of the country and therefore highly susceptible to infection, were assigned to these posts and training centers. In 1943, the number was 3,529,976.[9] This figure does not show merely the assignment of additional troops but probably indicates close to a complete replacement of men who had completed training and were now in combat zones. By 1944, the peak period of training had passed and the number of military personnel in the malarious regions had declined to 2,821,831[10] and by 1945 showed a further reduction to 1,908,520.[11]

MALARIA INCIDENCE IN THE UNITED STATES PRIOR TO WORLD WAR II

The last rise of malaria prevalence in this country to epidemic proportions occurred in the mid-thirties (see Chart 1) probably as a direct effect of the depression. Living standards deteriorated in most rural areas where malaria is traditionally focalized. As a result, those antimalarial defenses normally supported by householders (screening, drugs, insecticides) were relaxed. This outbreak constituted essential evidence on which was based the theory

of cyclical increases in the incidence of paludism in the United States.[12] [13] The fact that brief periods of high endemicity accompanied by scattered epidemics occurred historically in the United States at intervals of from five to seven years had been noted; and from this it was predicted that malaria prevalence would again reach a peak sometime near 1941 or 1942,[14] though it was not expected that this increase would be as important as its predecessors. In the first place, no further depression was anticipated which would paralyze resistance to such an outbreak. Secondly, the direction of over-all malaria incidence, including epidemic years, had been steadily downward ever since the last quarter of the nineteenth century and malariologists were not aware of any unusual circumstances which might reverse this trend.

INSERT CHART 1 NEAR HERE

Malaria, which at one time had been highly prevalent over a large portion of this country, had been concentrated since 1912 in the southeastern quadrant. The total area involved receded and expanded with the rises and falls in incidence of the disease until 1932 when it reached its minimal extent (see Map 1).[15] From that time until 1940, it remained at varying intensities in the same portions of the same States. It was in these regions

that many military and defense establishments were located when the United States put its World War II defense program into effect.

INSERT MAP 1 NEAR HERE

Since for the most part it is possible to maintain regular training operations in these areas throughout the year, the seasonal distribution of malaria was important only as it related to malaria control planning. In Georgia, for instance, a typical malarious State prior to World War II, the greatest number of cases was reported from July through November while deaths occurred chiefly from August through December.[16] This parallelism in trend and lag in the rise and decline in the numbers of deaths as compared to cases was typical of reported malaria in the southern United States. While the mortality and morbidity reporting of this disease have been notoriously inaccurate, especially before 1940, those responsible for the prevention and control of malaria have had to rely on them, plus the findings of special field surveys and diagnostic laboratories, as guides for operations. Thus, during the war years extra- and intracantonmental malaria control activities were based on this type of information.

The endemic areas of the United States have a climate compatible with the occurrence of both falciparum and vivax malaria,

though at higher temperatures the former flourishes somewhat more exuberantly than does vivax infection. While quartan malaria has been encountered occasionally in this country, it has never contributed significantly to morbidity and mortality.

The ratio between the number of cases and the number of deaths resulting from paludism is determined by the type of parasite involved. Vivax malaria is extremely debilitating to its victim and makes him liable to secondary infections which may prove fatal, but it is not generally a primary cause of death.[17] On the other hand, untreated falciparum malaria tends to fulminate rapidly and frequently kills its host directly. Thus, generally speaking, wherever there is a high ratio of falciparum infection, death rates

from malaria will be high; conversely, where they are low, malaria death rates are low. This factor appears to have manifested some influence on "cyclic" epidemic malaria in this country. During the last of these outbreaks, there was a greater proportional increase in the prevalence of falciparum malaria than of vivax. Judging by the sharp rises in mortality during previous epidemics, the same dominating role of falciparum parasitism may have been in operation.

Another factor which modified the occurrence of malaria in this nation was racial differences in susceptibility. Our white natives are readily infectible with all types of malaria parasites. On the other hand, the Negro is relatively refractory to vivax

malaria but can be a great reservoir of falciparum infection in the South. Furthermore, the easier access of anophelines to the poorly constructed and maintained cabins of the Negroes increased the numbers of their new infections, and the general unavailability of adequate treatment prolonged their parasitemias. Thus, the location of military camps in the Southeast where the adjacent colored population frequently outnumbered the white could have resulted in an enhanced exposure of training troops to the more deadly type of malaria, unless active measures were taken to forestall it.

Both vivax and falciparum infections are more prevalent during the warm seasons of the year than in the winter. In areas where they coexist, the pattern of P. falciparum incidence is the simpler of the two. It makes its appearance in the spring and increases very slowly. When warm weather arrives, the rate accelerates and a sudden peak is attained in the late summer or fall. In comparison, the P. vivax cycle is more complex in that it usually shows two separate increases during a season. The greater of these may coincide with or slightly precede that of P. falciparum. The lesser one manifests itself as a rule in the late winter or early spring months. These vernal attacks are either relapses of infections contracted and exhibited during the previous summer and fall, or represent primary onsets occurring after over-winter incubation.[18] This latter characteristic has been found to be

typical of temperate zone strains of vivax malaria.[19] [20] [21]

During the first World War, mosquito control operations were carried on within military reservations by the Army, and around camps, recreation areas, and war industrial plants in malarious regions by the U. S. Public Health Service to protect military trainees and civilian war industry workers.[22] Some $3,250,000 were spent by military authorities on drainage and oiling during 1918 and 1919.[23] No records are available to show just how much of the $2 millions appropriated by Congress to the U. S. Public Health Service for extracantonmental sanitation was used for malaria control - nor of the additional funds, labor, and materials contributed by the American Red Cross, railroads, State and county

health departments and, in some instances, by cities - but the total must have been considerable.[24]

In spite of these expenditures, 10,510 cases of malaria were reported among Zone of the Interior troops from April 1917 through December 1919, involving a loss of 130,673 training days.[25] This experience emphasized the necessity for devising more economical methods of malaria prevention. Therefore, studies on rural malaria control technology were continued after World War I, and cheaper temporary measures such as screening and larviciding were demonstrated and promoted in the years following. Parasitologic and entomologic studies were resumed by the U. S. Public Health

Service and State health departments. In 1932, the Bureau of Entomology in the U. S. Department of Agriculture established the Orlando Laboratory in Florida for the study of insects affecting man; this led to productive research in the entomology of malaria. Improvements in malaria reductive techniques included the demonstration of Paris green as an anopheline larvicide.[26] The extensive use of this substance brought about more effective and cheaper methods of application, including power dusting from trucks, boats, and airplanes. In 1923, the Rockefeller Foundation opened a malaria research station in south Georgia from which came many basic contributions and where the majority of the outstanding malariologists of this generation were trained.[27]

Another post-war development destined to become of great malariologic significance was the utilization of a traditional component of insect-killing dusts, pyrethrum, in kerosene as a spray.[28] This was introduced in 1919 but did not become popular as a household insecticide until about 10 years later.

Quinine had long been taken prophylactically by the residents of highly endemic areas to reduce the symptoms of malaria,[29] but it could not be depended upon to effect radical cures. While it may have interfered to some degree with malaria transmission, it is doubtful that it ever did so to any major extent. Atabrine was introduced in the early thirties and was promptly tested in

south Georgia with considerable success;[30] indeed, its intensive use may have modified the distribution of falciparum malaria in the South.

Since its creation in 1933 for the development of the Tennessee River system, the Tennessee Valley Authority has been interested in malaria control. The studies and operations of the Health and Safety Department of the TVA have resulted not only in significant reductions in the malaria and anopheline problems in this region but have provided the basis for improved water management principles and procedures which can be applied wherever water is impounded in potentially malarious areas.[31]

During the depression years and up to World War II, Federal relief organizations (the Civil Works Administration and Federal Emergency Relief Administration established in 1933, and the Works Progress Administration in 1935) supplied man-power for malaria control purposes.[32] A tremendous amount of drainage was accomplished through these projects. It has been estimated that the combined relief programs involved a daily average of 211,000 men for 6.5 years working on malaria-control drainage in an average of 250 counties.[33] In the 16 southeastern States, 33,655 miles of ditches were dug eliminating 5hh,hlh acres of anopheline breeding area.

The Social Security Act passed in 1935 and its extension

in 1939 provided for malaria survey and control personnel to be added to State health departments and for an increase in the number of local health departments through which antimalarial activities could be promoted and administered.[34] This stimulated the interest of States and counties in malaria control which, with operational assistance from the Works Progress Administration (Work Projects Administration), advanced environmental malaria control until late 1941. It was from these malaria survey and control teams in States that the Armed Forces were to draw so heavily for their own units.

CIVILIAN RESERVOIR OF INFECTION

The civilian population which constituted the reservoir in the southeastern United States from which military personnel were liable to infection was made up of underprivileged inhabitants - white and colored - of rural areas. For the most part they were tenant farmers, share-croppers, or hired farm laborers. Many were under-nourished and chronically ailing from secondary anemias due to their limited diet but frequently compounded by malaria and, in sandy coastal areas, by heavy hookworm infestation. Medical care was scantily available and beyond the financial reach of many of these families, so these defects were rarely corrected.

The principal forms of recreation of these people were

sitting out in front of their cabins in the hot summer evenings, fishing at night, and an occasional "sociable" which brought groups of all ages together after dark at country churches or schoolhouses. All these pastimes permitted free exposure to mosquitoes. Nor were these people much better protected against these insects when they were within their own homes for these structures were rude, ramshackle hovels, unscreened and with gaping holes in floors, sidewalls, and roofs providing easy access by nocturnally active, blood-hungry anophelines. Thus, malaria was continually maintained in this population at levels which were notably lower than those which had prevailed during previous generations but which in

many localities were still considerable. This was evidenced by high indices of blood parasitism and splenomegaly among school children.[35 36]

The construction and operation of military training camps offered lucrative opportunities to these people and many of them hastened to take advantage of them. In numerous instances they relocated their families near military installations thus bringing malaria parasite carriers into proximal relationship to military trainees. Added to this was the special risk of troops during maneuvers, night exercises, guard duty at night, and other details and activities entailing exposure to anophelines after dark. It is truly remarkable that more cases of malaria did not

develop among the military population. It seems reasonable to suppose that malaria would have been much more prevalent among the trainees had not effective measures been taken to minimize this hazard.

MOSQUITO VECTORS

On the basis of experimental infectibility, observed infection in nature, human-blood feeding habits, and epidemiologic correlation with the occurrence of human malaria, there are two species of mosquitoes which are the principal and possibly the only transmitters of malaria in the United States. These are Anopheles quadrimaculatus Say (see Fig. 1) found in the eastern and southern regions of this country and Anopheles freeborni Aitken (see Fig. 2) found west of the Rocky Mountains (see Map 2). A third species, Anopheles albimanus Wiedemann, an important transmitter of malaria in the Caribbean area, has been found in the lower Rio Grande Valley of Texas and rarely in southern Florida. However, since none of this species has been found naturally infected and since A. quadrimaculatus occurs in large numbers in the same areas, A. albimanus is not considered a malaria vector of any consequence in the United States.[37]

INSERT MAP 2 NEAR HERE

There are certain characteristics of these two important species of anophelines which are of significance in planning malaria control programs. A. quadrimaculatus and A. freeborni are primarily fresh-water breeders and are found more often in the clean, still, slightly alkaline waters of permanent or semi-permanent pools or ponds where surface-intersecting vegetation or

INSERT FIG. 1 NEAR HERE

nonvital flotage is abundant. In the larval microhabitat, A. quadrimaculatus is associated predominantly with mixed sunshine and shade or "broken shade" and A. freeborni with open sunlit water surfaces. Both species can tolerate considerable variation in and departure from optimal light values when the other ecologic factors favor oviposition and larval development. Thus, throughout the southeastern United States, A. quadrimaculatus thrives in large and small artificial impoundments, marginal river swamps, wet lime sinks, and flooded rice fields. In the west, A. freeborni is often associated with irrigation, being found in the seepage or overflow water from such systems or in their neglected grass-grown ditches.

Like A. quadrimaculatus, this species flourishes in rice fields and borrow pits, but, unlike its eastern counterpart, shows a propensity for temporary breeding places such as water-holding animal hoofprints and vehicle ruts. It can adapt itself successfully to brackish water (salinity equal to 15 per cent sea water), where its distribution carries it to coastal zones, and also to highly mineralized desert pools. The larvae of both species, in common with those of all other mosquitoes, are eagerly sought by the top minnow, Gambusia affinis. Under optimal conditions, the aquatic stages require at least ten days for their development.

The adults of these two species also have similar habits. Precipitin tests of the stomach contents of females of both species indicate a high proportion of bovine blood, with equine, porcine, and human appearing in decreasing amounts. Even though these mosquitoes are the nearctic anophelines most fond of human blood, these tests reveal that they prefer cattle hosts.

During the transmission season, both A. quadrimaculatus and A. freeborni enter homes without hesitation and rest in the darker corners and nooks in the day to emerge at night to feed; even larger numbers of them choose stables and other animal shelters.[38 39] A. quadrimaculatus also gather in tree holes, in caves, and under bridges and culverts.

While both species over-winter in the adult stage, their

habits in this period very somewhat. The fertilized A. quadrimaculatus females retire in the fall to dark sheltered spots such as unoccupied buildings, basements, root cellars, tree holes, and similar locations, usually in close proximity to breeding places, where they remain relatively inactive. On the other hand, during the fall and winter months, A. freeborni females convert their blood meals to fat-body rather than to eggs. After mating, they migrate for long distances, sometimes as far as ten to twelve miles from breeding areas, and seek shelter in outbuildings, houses, cellars, caves, and under bridges, without regard to the presence of man or other animals. Throughout the winter months, they manifest considerable activity, moving about and changing from one resting place to another. During this period of semi-hibernation, these mosquitoes are prone to bite man in warm buildings or even to attack him in the open on warm evenings. In February, the females emerge, bite viciously in full daylight, and continue their fall migration. This spring emergence and distribution flight is said to cover distances as great as the fall migration, but in a shorter period. At this time their eggs develop, oviposition occurs in both favorable and unfavorable breeding places, and within two or three weeks all the adult females disappear and only the larval stages are found. Within approximately a month, the first brood of adults for the new season appears.

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INSERT FIG. 2 NEAR HERE

The effective flight ranges of both species are usually considered to be about one mile, but it is known that longer flights occur occasionally.

DEVELOPMENT OF MILITARY MALARIA CONTROL PLAN AND POLICY

The outbreak of hostilities in Europe in 1939 set the United States defense program into motion. The President declared a limited national emergency, and the Congress passed the Selective Training and Service Act in 1940. By the end of that year, the training of troops had begun and industrial plants were being enlarged or constructed to produce the necessary materiel to supply not only our own needs but those of our future allies. Many munitions plants, airplane factories, and ship-yards were erected in the South where both space and man-power were readily available. Army posts and training centers were established also in this region where climatic conditions favored the year-round operations necessary to our all-out defense preparation effort. As a result of these activities, large numbers of individuals - both military and civilian - were introduced from other parts of the United States into these areas where malaria was historically endemic.

These new opportunities for employment cut heavily into the numbers of men on Work Projects Administration (Works Progress Administration) rosters. Thus, malaria control drainage projects previously manned by this organization tapered off rapidly.

On military property, Army authorities operated malaria control activities, but they were not authorized to extend these to adjacent civilian establishments and domains certain to be used by trainees, nor to undertake them on and about the areas where defense industries essential to the future war effort were located. Experienced State malaria control and survey teams were being drawn upon heavily for staffing the Army malaria control organization; thus, State health departments were unable to assume this responsibility.

Fortunately, arrangements had already been effected through an interchange of communications early in 1940 between the Secretary of War and the Federal Security Administrator whereby the U. S. Public Health Service, operating under the authority of existing laws and using its own resources, was to cooperate with the Army "in safeguarding the health of military personnel by suitable measures of extramilitary area sanitation in connection with the present concentration of troops in the South."[41] This had been developed initially to help check the increases in venereal diseases acquired by soldiers from civilians. For this pur-

pose, liaison personnel had been detailed during or shortly after November 1940, by the U. S. Public Health Service[42] to each Corps Area Headquarters to effect operational contact between military and civilian health authorities during maneuvers. This provision was quickly extended to include extracantonmental zones.[43] The existing authority was broad enough to carry on extramilitary malaria control activities under the same auspices, and so it was proposed originally to operate malaria mosquito control projects around camps through these liaison officers, the State health departments, the Work Projects Administration, and the District Offices of the U. S. Public Health Service.[44] However, experience during 1941 proved the infeasibility of this procedure and in early 1942 the Army requested information concerning future plans of the U. S. Public Health Service regarding extramilitary mosquito control activities.[45] Shortly thereafter, the U. S. Public Health Service activated a special organization[46] known ultimately as the Office of Malaria Control in War Areas, generally referred to as the "MCWA", to direct and coordinate the efforts of Federal, State, and local health agencies near military establishments, and to help integrate on an area basis the malaria mosquito control activities of military and civilian workers.

Thus, two related but separately administered programs of insect control were carried on in the United States to protect the

health of military personnel and war industry employees in World War II. The first of these was directed, executed, and financed by the Army on Army property. It was aimed at reducing the number of all pestiferous insects - whether or not they transmitted malaria or any other disease - as the Army has always recognized the important role of all insect pests in decreasing the morale, comfort, and efficiency of troops.[47] Thus, it is not possible to identify from existing records the volume of work done nor money spent by the Army for malaria mosquito control alone.

The second program was directed and coordinated by the U. S. Public Health Service and executed by this organization with the collaboration of State and local health departments. It was supported by funds appropriated for "Emergency Health and Sanitation Activities"[48 49 50 51 52 53 54 55 56 57] and was designed solely to prevent malaria transmission on civilian property used by military personnel and civilian war industry workers.

MALARIA CONTROL ACTIVITIES WITHIN MILITARY AREAS

The story of intramilitary malaria control activities within the Zone of the Interior is related in other chapters of this History.[58 59 60] It is the purpose of this section to supplement that information where possible, to indicate the magnitude

of the total accomplishments, and to estimate the probable impact of these events on the prevalence, control, and prevention of paludism in this country during peacetime and in future wars. In this connection, it is important to recall that it was during the World War II years that advances were made in anti-vectoral malaria control technology which were probably of greater consequence than any other preventive information developed since Ross solved the mystery of malaria transmission just before the turn of the century. These improvements changed the emphasis in type of anti-malaria activity within and beyond military reservations from 1940 to 1946, and this, in turn, resulted in a shift in the professional direction of anti-anopheline and other insect control operations on military establishments during and since World War II. The new procedures, first practiced by the Army, led to an enlargement of the civilian objectives of malaria control from incomplete reduction of morbidity in limited areas to total eradication of the disease from large ones.

It has been shown elsewhere[61] that the organizational responsibility in the Army for the control of insects, including anopheline mosquitoes, was not clearly defined in 1940, and that it underwent substantial evolution during the early years of defense preparation and actual engagement in World War II. To recapitulate briefly, the probability of malaria incapacitating

training troops in southern camps was recognized in 1940 within the Preventive Medicine Service of the Office of the Surgeon General. Immediate responsibility for planning, organizing, staffing, and financing malaria mosquito control was assumed by the Sanitary Engineering Division of that Service as it was evident that the Quartermaster Corps, traditionally liable for such activities, would be unprepared to cope with an anopheline reduction program of such unprecedented magnitude by the time operations should be commenced in 1941 to protect troops quartered that summer in southern camps. Thus, for the balance of fiscal year 1941, the malaria mosquito control operations in the continental United States were funded by the Medical Department and executed under the immediate direction of Medical Department personnel (see Map 3). On 1 July 1941, the nominal work responsibility was resumed

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and the program was financed by the Quartermaster Corps though the activities were actually directed for the rest of the mosquito season by the Medical Department.

On 1 December 1941, responsibility for the entire Army construction, maintenance, and repair - including insect and rodent control - was transferred by law[62] from the Quartermaster

Corps to the Corps of Engineers. The continental mosquito control program was taken over by the Corps of Engineers on 16 December 1941[63] and was operated by them thereafter in accordance with their provisions[64] and the recommendations of the Medical Department and under such Medical Department technical guidance as was necessary.[65] Until 1 July 1943, these activities were nominally supervised and coordinated in the Repairs and Utilities Division of the Office of the Chief of Engineers[66] though the Sanitary Engineering Division of the Preventive Medicine Service, Surgeon General's Office, continued to provide much professional guidance and direction.[67] These included budgeting funds; authorizing post engineers to employ supervisors, foremen, and laborers for the execution of control measures; and supplying specialized equipment and materials for use by the Corps of Engineers.[68] Service Command engineers consolidated estimates of mosquito control costs submitted from camps and posts, and exercised general coordination of the work. This included drainage, filling, ditch lining and stabilization, clearing, cleaning, and larviciding with oil, Paris green, and other chemicals (see Fig. 3). Post engineers directed these operations and made estimates of future costs with the assistance of Sanitary Corps engineers and entomologists assigned for the most part to installations in the South.

INSERT FIG. 3 NEAR HERE

With all the insect control sanitation accomplished during the early years of the war effort, it might be assumed that the continental malaria hazard on military areas would have diminished to a negligible level. However, the rotation home of troops from malarious areas overseas plus the importation of prisoners of war and labor battalions from endemic areas abroad resulted in the frequent and almost continuous introduction on or near Army installations in the Zone of the Interior of clinically obvious cases of malaria and undoubtedly many more asymptomatic carriers of malaria

parasites. It was proved experimentally by U. S. Public Health Service scientists that the native anopheline vectors in this country were infectible with and could transmit extracontinental strains of malaria organisms.[69] Thus, it was necessary until the end of the war to maintain a constant vigilance to discover previously unknown sources of anophelism and to evaluate repeatedly the results of antimosquito efforts (see Map 4). This required

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ecologic knowledge of these insects beyond that possessed by most

engineers, and a more thorough and extended familiarity with the terrain of camps than could be developed by Sanitary Corps entomologists detailed to them for brief periods.

By 1 July 1943, the program had become so large and technically exacting that an Insect and Rodent Control Section was organized in the Repairs and Utilities Division, Office of the Chief of Engineers,[70] and placed under the direction of an experienced entomologist. Lieutenant (later Lieutenant Colonel) W. Doyce Reed, Sanitary Corps, was detailed to duty with the Corps of Engineers to fill this position, and Captain (later Major) George D. Jones, Sanitary Corps, was assigned as his assistant. The establishment of Insect and Rodent Control Sections in the Offices of Service Command Engineers was also authorized together with the appointment of technically trained professional entomologists. This had the advantage of providing competence not only against vectoral and pestiferous insects but also against property-destroying species of arthropods with which the engineers were now obliged to deal. The duties of the Service Command entomologists, as far as mosquito control was concerned, were to promote and coordinate these activities at post level,[71] to assist post engineers in planning and executing these operations, to prepare field instructions concerning them, to review insect control budget estimates made by post engineers for installation commanders, and to maintain liaison

pressure sprayers (see Fig. 5) and in the rotary, hand-operated dusters supplied by the Corps of Engineers for mosquito control.

INSERT FIGS. 4 AND 5 NEAR HERE

Table 1 summarizes the intramilitary mosquito control work accomplishments and costs for the five fiscal years for which data are available. During this period, approximately 70 per cent of the funds budgeted for insect and rodent control were spent for mosquito reduction. These expenditures, amounting to $11,584,525,

between the Corps of Engineers and the Medical Department, the Quartermaster Corps, and the U. S. Public Health Service with reference to mosquito control plans and activities. Post engineers were authorized to hire civilian labor who executed all mosquito control activities on posts, except where Medical Department units were stationed for mosquito control training purposes. This was all done in compliance with Medical Department recommendations and requirements.

Developmental work was conducted in cooperation with the Engineer Board, Fort Belvoir, Virginia, for the improvement of equipment used in the dispersal of insecticides.[72] A new 3-gallon knapsack sprayer was developed to replace the old 5-gallon type (see Fig. 4). Improvements were also made in mechanical high-

Table 1.--Summary of Continental Mosquito Control Operations on Military Property

Fiscal Year	New ditching or channelling (lin. ft.)	Clearing or brushing (acres)	Channel or ditch cleaning (lin. ft.)	Fill (cu. yds.)	Ditch lining (lin. ft.)	Water surface eliminated (acres)
1941	1,008,530	1,773	1,245	130,987	10,554	
1942	3,414,144	66,598	12,297,940	1,912,649	419,926	15,340
1943	3,353,454	97,579	14,525,922	3,018,973	586,796	17,532
1944	684,108	20,172	8,876,952	691,848	269,950	6,575
1945	488,161	17,379	4,648,972	666,059	113,082	4,383
TOTALS	8,948,397	203,501	40,351,031	6,420,516	1,400,308	43,830

Fiscal Year	Diesel oil larvicide (gals.)	Paris green larvicide (lbs.)	Other larvicides (gals.)	5% DDT in oil (gals.)	Expenditures
1941	100,553	1,920	4,849		$1,058,000
1942	1,704,645	45,904	241,161		$3,000,000
1943	1,591,002	33,384	129,193		$3,591,205
1944	1,236,430	2,403	36,441	45,102	$2,159,717
1945	1,150,073	1,771	23,841	80,155	$1,775,603
TOTALS	5,782,703	85,382	435,485	125,257	$11,584,525

TABLE 1.--Summary of Continental Mosquito Control Operations on Military Property (cont.)

Source: For FY 1941- April, May, and June Mosquito Control Reports for 4th and 8th Corps Areas. Other Corps Area reports were not available, but it is believed that they would not have increased the totals shown by more than 25 per cent. The "expenditures" for 1941 is quoted from Hardenbergh (see footnote 58 in text). It is probable that about 70 per cent of this figure represented funds obligated in FY 1941 for materials and purchases delivered after 30 June 1941.

For FY 1942, 1943, 1944, and 1945- MCE-8 and 5-123 (Monthly Mosquito Control Activities) Reports, extracted and consolidated by Lieutenant Colonel W. Doyce Reed, Sanitary Corps, as shown in "Malaria Control History - World War II - Corps of Engineers" (see footnote 66 in text).

were made at military posts, camps, and stations totalling in area some 12,758,138 acres. Of these, approximately 1,164,855 acres were improved and maintained grounds where about 55 per cent of the total outlay were made for permanent mosquito control measures. The remaining area (11,593,283 acres), consisting largely of rough terrain, received temporary treatment such as larviciding and residual spraying.

In addition to setting forth the substantial dimensions of the total enterprise, Table 1 shows that the antimosquito efforts changed materially in character and emphasis from 1 July 1943, with a decided shift away from heavy physical and costly operations aimed at destroying mosquito breeding areas by dewatering them. Much of the decrease in drainage, filling, and related activities was undoubtedly due to the fact that less remained to be done after

1 July 1943 because of previous accomplishments. It is believed, however, that this sharp reduction also reflects more careful and conservative technical discrimination, based upon entomologic considerations, in selecting for ditching or filling only those watered areas which were actually producing mosquitoes and the elimination of projects whose financing was not properly allocable to mosquito control funds.

Another factor of importance in the shift of emphasis from FY 1943 to FY 1944 was the advent of DDT. The effectiveness

INSERT FIG. 6 NEAR HERE

of this new and potent weapon against mosquitoes and numerous other vectoral and pestiferous arthropods was verified in the Orlando Laboratory of the U. S. Department of Agriculture.[73] This remarkable compound became available in quantity for military use in the spring of 1944[74] and was effective either as a larvicide or as a residual insecticide. It could be dispersed by manually operated sprayers, mechanized spraying, or fogging equipment, or from airplanes (see Fig. 6). However DDT was applied, its distribution to secure maximum effectiveness without damaging consequences to wildlife required a fairly comprehensive biological understanding, thus justifying further the entomologic direction of the insect control activities within the continental United States. Within a brief period, residual DDT (see Fig. 7) decreased the necessity for and took the place of many other mosquito control measures. The demonstration of its unprecedented antianopheline effectiveness upon military premises during the last two years of the war led to its employment in 1945 in the Extended Malaria Control Program (see below) which was later phased into the National Malaria Eradication Program carried on cooperatively by the U. S. Public Health Service and various State health departments.[75]

INSERT FIG. 7 NEAR HERE

Table 1 also indicates that diesel oil remained the larvicide of choice, presumably because of its destructive effect against both culicine and anopheline larvae and pupae, as well as its easy visibility on water which facilitates checking its recent application. Its use decreased slightly from year to year but not in proportion to the amount of water surface eliminated. Thus, it is evident that a considerable extent of breeding area remained which could not be drained or filled practicably. Paris green, which kills only anopheline larvae, and other larvicides, except diesel oil and DDT, were virtually discarded after the entomologists were placed in charge of insect control activities.

That these activities, supplemented by the U. S. Public Health Service Malaria Control in War Areas program, were successful from the standpoint of preventing malaria is manifested (1) by the low levels of hospital admissions for malaria among military personnel quartered in the United States, and (2) by comparison with similar hospital admission rates during World War I. These are shown in Table 2.

TABLE 2.--Hospital Admission Rates for Malaria in the Continental United States

Years	Rates*
1917	7.5
1918	3.9
1919	3.6
1941	1.7
1942	0.6
1943	0.2
1944	0.2
1945	0.1

* Per 1,000 per annum, excluding malaria acquired overseas.

Source: Statistical Health Reports, WD AGO Form 8-122 (formerly WD MD 86ab), Medical Statistics Division, SGO.

MALARIA CONTROL ACTIVITIES AROUND MILITARY AREAS

Because malaria was the greatest menace to military training in the southeastern section of the country, the Surgeon General of the U. S. Public Health Service assigned his chief malariologist, Medical Director (Colonel) Louis L. Williams, Jr., to the liaison detail with the Fourth Corps Headquarters, Atlanta, Georgia, on 13 November 1940.[76] Dr. Williams served in this capacity for over a year assisting State health departments, Corps Area personnel, and the Army Surgeon General's Office[77] in planning and executing malaria control projects on and near military bases. He was relieved 9 February 1942 and ordered "to remain in Atlanta,

Georgia, to establish headquarters in connection with malaria control."[78] After serious deliberation as to whether this mission might best be fulfilled through existing U. S. Public Health Service District Offices or by a special, nation-wide organization, the decision was made for the latter, and Dr. Williams proceeded with the difficult task of assembling and organizing a malaria control staff.

The proposed plans, policies, and procedures of this organization were announced in two of the Extra Military Zone Circular Letters, a special series of communications issued by the Surgeon General for the guidance and coordination of U. S. Public

Health Service Liaison Officers and District Directors, State health officers, the Work Projects Administration, and others concerned in the reduction of extramilitary health hazards. The first of the letters pertaining to the Atlanta malaria control headquarters was released on 10 February 1942.[79] This refers to the organization as the "National Defense Malaria Control Activities", though current letterheads show that "Malaria Control in Defense Areas" was the name actually in use. On 20 April 1942, this name was changed officially "in conformity with the trends of the times" to "Malaria Control in War Areas",[80] and the Circular Letter of 27 April 1942,[81] which superseded its predecessor, confirms the designation by which the organization was subsequently known.

This document stated that extramilitary malaria control activities would be confined to malarious areas; that pest mosquito control would not be undertaken;[82] and that appropriated funds would be available to employ labor directly, to purchase equipment and supplies, to provide technical supervision of drainage projects operated by the Work Projects Administration, and to construct essential drainage facilities where the resources of the Work Projects Administration were insufficient. Operations were to be restricted to areas (1) contiguous to military establishments or essential war industries, (2) where large numbers of military personnel congregated, and (3) within or near housing develop-

ments for war workers. It specified the States, Territories, and Possessions in which these activities would be authorized. It indicated that the Office of Malaria Control in War Areas would function as an individual unit separate from the other Emergency Health and Sanitation Activities of the U. S. Public Health Service, and that its authority would be exercised and its responsibility discharged in collaboration with the U. S. Public Health Service District Offices. Every effort was to be made to secure and utilize funds and other resources through State and local agencies. Lastly, it defined the respective roles, relative to malaria control, of its Headquarters Office, the District Offices, and the cooperating State health departments. The important principles embodied in these definitions were -

(1) That State health departments would perform the necessary surveys, plan, and operate the malaria control projects, supervising U. S. Public Health Service personnel assigned to them for these purposes;

(2) That the Office of Malaria Control in War Areas would formulate policies governing the operation of the program; execute administrative control of and assume responsibility for fiscal, personnel, and supply

considerations; and exercise general technical supervision and coordination of projects and project operation; and

(3) That District Offices would accept responsibility for Federal-States relations, assist in program planning and policy formulation, and collaborate in exercising general supervision over project operations.

Chart 2 shows that the Malaria Control in War Areas derived its authority from the Surgeon General, U. S. Public Health Service, through the Division of States Relations which in November 1943 became a division in the newly created Bureau of State Services.[83] The military urgency of its mission and the broad geographic scope of its operations made this organization unique in the history of the U. S. Public Health Service. It was wisely recognized by officials at both Bureau and Division levels that to succeed in its objectives, the program must be allowed an unprecedented degree of autonomy and freedom from Washington domination. They encouraged rapid expansion and assisted in relaxing the usual strictures of government procedure in personnel and procurement actions. By the end of June 1942, Dr. Williams had obligated approximately $1,400,000 and had put 2,600 men to work in 93 areas within 15 States, the District of Columbia, and Puerto Rico.[84]

INSERT CHART 2 NEAR HERE

Collaborative relations with other Bureaus and elements of the U. S. Public Health Service are also indicated in Chart 2. On this basis, Malaria Control in War Areas entomologists were detailed to international airports where they assisted U. S. Public Health Service Foreign Quarantine authorities in excluding insect vectors of malaria and other diseases.[85] Investigations were carried on with the National Institute of Health to determine whether or not native anophelines could transmit foreign strains of malaria parasites imported with infected military personnel. The Office of Malaria Control in War Areas depended largely on the U. S.

Public Health Service Liaison Officers for coordinating its efforts with those of military health authorities, and upon the District Offices for initiating its program relations with States, for handling special problem situations, and for operating the activities in marginal States where the work volume did not justify a special Malaria Control in War Areas unit at State level.

The organizational plan of the Office of Malaria Control in War Areas varied somewhat from time to time, but Chart 3 is representative of its structure. With the exception of the *Aedes aegypti* Division (discussed below under "Related Activities"), it

INSERT CHART 3 NEAR HERE

was laid out primarily on a professional category basis, though its activities were invariably characterized by a high degree of team work in planning and execution. The staff was composed for the most part of commissioned personnel from other elements of the U. S. Public Health Service, or recruited from other Federal or State agencies, and from universities. From the beginning, engineering and entomologic competences predominated, which was consistent with the nature of the operational objectives. Medical and parasitologic skills were recruited primarily for malariometric purposes in the field and in the laboratory, respectively. Training and health

education specialists were acquired to carry on in-service training and a program of lay health education concerning malaria and its prevention. A relatively unique but indispensible adjunct of the organization was the Equipment Unit which was located in the Henry Carter Memorial Laboratory at Savannah, Georgia, where its professional and technical personnel developed new and improved equipment, materials, and procedures for use in malaria control.

Prior to the war, several of the southern States had developed basic organizations for malaria survey and control. These usually included a physician, an entomologist, and an engineer, a

team which could locate and confirm malaria cases, appraise the local transmission potential, and initiate desirable control measures. This concept was accepted and actively promoted by the Malaria Control in War Areas in developing its field organization. In certain States, supervisory personnel had to be provided to replace or strengthen the staff of the State director of malaria control. The most frequent and pressing needs were for entomologists to train inspectors and to assist in organizing and checking field and laboratory activities, and for engineers to plan and supervise operations. Administrative and clerical personnel were also assigned where necessary. All of these individuals were directly responsible to the State director of malaria control in the State to which they were detailed. In some instances, this individual was the State health officer; in others, the director of preventable diseases, the State sanitary engineer, or a full-time malariologist without other duties.

Recruiting and training on such short notice the large force of professional specialists; technical, administrative, and clerical assistants; and both skilled and unskilled labor needed to carry on the Malaria Control in War Areas activities would have been extremely difficult in normal times. In the face of mounting draft quotas and the high pay offered by war industries, it seemed impossible. It is the more remarkable that this technical opera-

tion which required some 3,300[86] employees before the end of 1942 and a maximum of 4,556[87] in August 1945 was accomplished with relatively few requests for deferment.

Actual operations were carried out almost entirely by the States, each State directing its own program through existing administrative channels and on the basis of its own legal authorization. Assistance from Malaria Control in War Areas, in addition to trained personnel, consisted of specialized equipment, materials under war-time priority, technical development and consultation, advice on administrative and fiscal matters, training and training aids, and laboratory services.[88] In the States where malaria had

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been endemic in the past, there were in 1942 some 900 so-called "war establishments" to be protected; by January 1945, the total had risen to approximately 2,000.[89] These included military posts, camps, stations, bases, hospitals, depots, air fields, Navy Yards,

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INSERT MAP 6 NEAR HERE

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other military port areas, staging areas, prisoner-of-war camps, maneuver areas, access highways, extramilitary recreational centers,

none of these was satisfactory because of the short time available, the paucity of trained medical investigators, and the general low prevalence of the disease. Ultimately, it was decided that the safest procedure was to base and evaluate malaria control activities on evidence of vectoral anopheline, on the thesis that the presence of malaria transmitters is a potential hazard even though malaria cases or parasitism may not be demonstrable in the area.[92] When the density of malaria-carrying species of mosquitoes was considered significantly high, a "control zone" one mile in width[93] was established around the military installation. All breeding places were located and spotted on the area map. Adult mosquito-

shipyards, airplane factories, ordnance works, other essential war industries, housing developments for war workers, etc. These war establishments were grouped, according to location and the nature and extent of the problem, into some 250 "war areas", and an area supervisor, usually an engineer, was placed in charge of the malaria control activities to be carried on around each group of war establishments. He worked closely with the sanitation officers on adjacent military installations and with the local health officers. Thus, the war area was the geographic unit of operations.[90]

Efforts were made by the medical epidemiologists to get current, reliable appraisals of malaria prevalence near these war establishments using conventional methods of malariometry[91] - but

catching stations were selected in representative locations so that the results of mosquito control operations could be assessed entomologically.[94]

The area supervisor then visited and studied the control zone around the war establishment, usually with the entomologist. He observed the type and extent of the anopheline breeding places, and decided what type of antilarval procedure - larviciding, minor drainage, or major drainage - would be most effective, feasible, and economical,[95] and whether or not it could be constructed or operated in conjunction with the intramilitary mosquito control activities. On the basis of these observations, he made cost estimates, planned a work program for the entire war area or areas under his supervision, requisitioned the necessary vehicles, equipment, and supplies, hired and trained inspectors, foremen, and laborers, and proceeded with the anti-mosquito operations. The activities and accomplishments of his crews were reported to the State Office, Malaria Control in War Areas, at prescribed periods, though certain of the entomologic findings were sent directly to the Atlanta headquarters where current information with which to answer official inquiries was maintained about the status of each project.[96]

In States where the anopheline hazard was not sufficiently extensive or continuous to warrant maintaining State organiza-

tions for Malaria Control in War Areas, malaria mosquito control service was rendered as needed by mobile units.[97] These were developed to provide surveillance around isolated war establishments such as Army General Hospitals or prisoner-of-war camps in States of marginal endemicity and to take action in case vector densities indicated the need for control. Each unit consisted of a passenger vehicle and a heavy truck containing the supplies, material, and equipment necessary to conduct surveys and inspections and to execute larvicidal or minor drainage operations. An entomologist or engineer was in charge of each unit and was responsible to the Office of the U. S. Public Health Service District in which the unit operated. The officer in charge hired his assistants and laborers locally. Arrangements for the assignment of units to areas within States were made between the District Office personnel and the health officers of the States involved. Each unit operated under the jurisdiction of the health officer of the State to which it was temporarily assigned. In 1944, two mobile units were assigned to each of two U. S. Public Health Service Districts and one each to four other Districts. Others were held at the Atlanta headquarters for emergency use.

The task of procuring supplies and equipment to implement these far flung operations was a mammoth and continuing one. In arduousness, it was surpassed only by the problem of finding

competent and industrious personnel. Wartime priorities and the scarcity of certain items added to its complexity. The acquisition of automotive equipment was an early necessity which never ceased to be a critical one. The Appropriation Acts prohibited the purchase of new or used passenger-carrying vehicles without special authorization - and during the war years such permission was virtually impossible to obtain. Thus, the most efficient utilization of equipment on hand was imperative. Fortunately, at that time there was no regulation against the inter-departmental transfer of vehicles on a reimbursable basis and at the start of the program, 79 cars and trucks were so obtained from the Army.[98] Other vitally

needed pre-war equipment was transferred from the Work Projects Administration and the National Youth Administration.[99] More was acquired through the ingenuity and resourcefulness of those charged with this responsibility. By the end of the war, the inventory of the Malaria Control in War Areas carried a total of 1,046 separate kinds of items ranging from $12,000 draglines to rat traps.[100] According to its official property records, vehicular units included at that time three airplanes, about 250 passenger cars, and roughly 2,000 trucks.

With such a highly dispersed operation carried on under duplicative authority and virtually autonomous State direction, the problem of coordination and integration and the maintenance of high

standards of work performance was a most complex and challenging one. It was solved to a remarkably high degree by means of personal visits of headquarters staff to field operations sites, of annual conferences in Atlanta of District and State operational personnel who gathered to discuss and mutualize their experiences, and of several types of official communications issued by the Atlanta office.

The first of these was a Manual of Operations which consisted of a loose-leaf series of mimeographed Manual Letters issued at irregular intervals starting 30 March 1942.[101] The primary purpose of these letters was to interpret Extra Military Zone Circular Letter No. 8,[102] and to guide the operation and administration of the program.[103] It was intended for the Manual to discuss items of a relatively permanent nature. Information and instructions of a more temporary category were transmitted as Field Memoranda, mentioned below. Each supervising employee was issued a copy of the Manual for his guidance and the letters in it were frequently revised. Thus, it served as a medium for maintaining current contact between the Office and the field, providing the latter with statements of policy, operating and administrative instructions, directives, and information concerning procedural improvements based upon group experience, research, and other activities. As of 1 July 1943, the Manual Letters were revised and reissued in separate

numerical sequences for each of the following Sections: Introduction, Administration, Engineering, Entomology, Training, and Medical.[104]

On 27 August 1943, the first of 69 numbered Field Memoranda made its appearance.[105] These were used to convey announcements, directives, program notes, and instructions pertaining to administration or operations but were of a more transient significance than the contents of the Manual Letters.

Activities data were consolidated in State headquarters and in Atlanta to form tabular summaries by States of (1) areas in operation, (2) war establishments protected, (3) accounts of lar-

vicidal activities in terms of amounts of larvicides used and of areas treated, (4) minor and major drainage accomplishments, (5) areas of water surfaces eliminated, (6) man-hours required, and (7) personnel and payroll by category. To the statistical information were added brief but profusely illustrated narrative interpretation, comments about the various programs and organizational units, job and materials specifications, news items, and technical features such as insect identification keys, field and laboratory tests, special survey reports, etc. These were reproduced and distributed to all concerned starting in July 1942 and continuing through March 1944. The first of these was titled "Organization Report in Lieu of Monthly Report of Malaria Control in War Areas."[106]

Succeeding issues were called "Monthly Reports, Office of Malaria Control in War Areas."[107] Essentially the same material was distributed for the remainder of the calendar year as the "Field Bulletin, In-Service Training and Information, Malaria Control in War Areas", and beginning in January 1945 it was captioned the "Malaria Control in War Areas FIELD BULLETIN."[108] Through July it was sent out each month, but by the end of 1945 it had become first a bimonthly and then a quarterly release. This was continued to the end of fiscal 1946 when the Office of Malaria Control in War Areas was terminated. At the close of each fiscal year from 1942 through 1946, annual consolidations of these reports were developed with many illustrations, tables, analyses, conclusions, and special accounts of State and District malaria mosquito control activities.[109] These volumes were also given wide distribution.

All of this reportorial material was prepared skillfully with an awareness of its educational and integrative possibilities. In an unobtrusive fashion, it kept the staff and employees of Malaria Control in War Areas at all organizational levels and in all States and Districts well informed regarding the dimensions of their total effort. Thus, it had much to do with catalyzing the development of the notable esprit de corps which prevailed throughout the organization. Lastly, it provided for future reference a detailed record of procedure and accomplishment, even under the

stringencies of wartime conditions, in steadily reducing an age-old menace to health and prosperity by exerting the combined efforts of military, Federal, State, and local health agencies.

A summary of activities based on information from these sources is shown in Table 3. This includes the costs, by fiscal years, of antimosquito activities from 1942 through mid-1946, one year in addition to the period covered in the otherwise comparable analysis of similar operations on military establishments within the country (see Table 1). This is because it was considered necessary for the Malaria Control in War Areas to continue its wartime anti-anopheline program around military areas after V-J Day, since service personnel continued to return to separation centers for demobilization. Among them were many who, as in 1945 (see Chart 1), still suffered from recurrent attacks of malaria. These individuals were treated in Army general hospitals if their attacks occurred before separation; if they came afterward, they sought relief mainly in Veterans Administration facilities, and also from private physicians or by self-medication. Consequently, it was believed prudent to keep the malaria vector density reduced around the Federal establishments in which malaria cases were concentrated, and in endemic or formerly endemic rural areas of the country where it was known that malaria relapses were occurring in veterans.

TABLE 3.--Summary of Continental (and Puerto Rico) Mosquito Control Operations near Areas of Military Importance

Fiscal Year	Larviciding			Drainage				
	Diesel oil (gals.)	Paris green (lbs.)	Acres treated	Clearing (acres)	Ditching (lin. ft.)	Cleaning (lin. ft.)	Fill (cu. yds.)	Acres drained
1942	281,880	11,432	18,000*	1,148	5,121,697@		239	?
1943	1,876,607	152,267	198,208	12,940	6,715,761	22,805,651	60,009	8,161
1944	1,527,008	155,735	268,504	8,035	6,015,316	42,769,486	79,230	6,878
1945	1,003,168	132,283	214,666	3,942	740,663	9,547,875	76,954	637
1946	1,003,518	132,274	129,897	3,938	742,438	9,547,855	76,954	1,024
TOTALS	5,692,181	583,991	829,275	30,003	19,335,875	84,670,867	293,486	16,700

* Estimated by adding the ponded area to twice the linear footage of treated ditches, assuming an average width of two feet.

@ Includes "cleaning".

TABLE 3.--Summary of Continental (and Puerto Rico) Mosquito Control Operations near Areas of Military Importance (cont.)

Fiscal Year	DDT Spraying		Expenditures
	DDT (lbs.)	Houses Sprayed	
1942			$1,400,000
1943			$6,147,000
1944			$6,571,117
1945	103,957	264,482	$8,494,968
1946	694,365	1,025,381	$9,047,616
TOTALS	798,322	1,289,863	$31,660,701

Source: See footnotes 84, 107, 108, and 109 in text. In addition to expenditures for anti-anopheline activities in this country and Puerto Rico, the table includes relatively minor outlays made for Aedes aegypti control in the United States and the Territory of Hawaii (see under "Related Activities").

Table 3 emphasizes the fact that larvicidal measures were basic in the early years of the extramilitary War Areas program, as the desirability of permanent destruction of anopheline breeding places had to give way to the expediance of using more immediately beneficial measures. The first such project operated under the Malaria Control in War Areas was commenced on 17 March 1942 in Florida.[110]

Oil was the most common larvicide used except in such places as Puerto Rico where the costs of transportation made it prohibitive. While not as economical as Paris green which kills only the larval stages of Anopheles, oil was preferred by personnel operating local programs since its application served the dual purpose of destroying all the aquatic stages of pest mosquitoes as well as anophelines. This made the program more popular with the residents of the area and usually secured their cooperation. In some zones, it was used exclusively and accounted for the bulk of the financial and labor expenditures. During early 1942 and fiscal year 1943, more than 2.1 millions of gallons were applied on nearly 115,000 acres of breeding area using 3,577 hand sprayers, 13 power sprayers, and 19 oil-water units.[111] In this and other field activities, power equipment was advocated wherever feasible both to expand control operations without increasing manpower requirements and because it generally cost less. Thus, in 1944 power equipment

war. It was cheaper than oil and was especially useful in treating watered areas overgrown with aquatic plants, as the dust mixture did not cling to the overgrowth as did oil. Furthermore, Paris green mixtures had a much wider potential radius of application than did oil sprays under identical meteorologic conditions so that less accessibility to breeding places was required. In relatively small areas which could be approached by men on foot, the usual method of spreading Paris green was by means of rotary hand dusters. Under favorable atmospheric circumstances, the mixture would be airborne for distances up to 150 feet. In larger areas, power dusting from trucks and boats was more practical and economical.[115] Early in August 1942, because of prolific A. quadrimaculatus breeding within flight range of important military establishments near Washington, D. C., it became necessary to larvicide approximately 3,500 water-chestnut infested acres along the Potomac River and its tributaries. The growth was so dense as to preclude dusting from boats, and it was decided to try airplane application for this project (see Fig. 8). It turned out to be both effective and economical. Thus, the use of airplane dispersal for larviciding was introduced into the Malaria Control in War Areas program.[116] Prep-

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arations were made immediately to use it more extensively during the 1943 season, and by 30 June 1943, four airplane dusting projects were in operation at New Orleans, Louisiana, Newport and Walnut Ridge, Arkansas, and Greenville, Mississippi. During the second year of Malaria Control in War Areas operations (1943-44), airplanes were used on contract on nine projects in the States of Virginia, Mississippi, Arkansas, Louisiana, Tennessee, and in Puerto Rico.[117] About 350,000 pounds of 25 per cent Paris green mixture were applied in 64,780 acre-applications. The effectiveness of airplane dusting varied widely, being lowest in irregular, wooded swamps and at its best on areas covered with low aquatic vegetation as in the Potomac River water-chestnut project. During fiscal year 1944, 187,799 acre-treatments of Paris green were made - 45 per cent by hand, 21 per cent by power duster, and 34 per cent by airplane. Respective costs per application were $2.98, $0.65, and $1.06. Dust mixtures varied from 4 to 10 per cent by weight for hand and power dusting and from 15 to 25 per cent for airplane application. Rates of application were from one-half pound of Paris green per acre in relatively clear areas, to two pounds per acre in densely vegetated areas or in high-flying airplane operations over swamps. The average application rate was 1.3 pounds per acre.[118]

There was a substantial decrease in hand larviciding -

war establishments, drainage had to be secondary to the more rapid methods of malaria control. The general rules of the Malaria Control in War Areas with respect to drainage priority were (1) to consider minor drainage operations normal adjuncts of the larviciding activities, and (2) to undertake major drainage construction where effective control by larviciding could not be achieved without drainage or where the cost of effective larviciding was greater than that of drainage.[120]

From 17 March to 30 June 1942, the Malaria Control in War Areas attempted very little major drainage construction as this was being carried on by the Work Projects Administration within

oil and Paris green - in the 1944-45 season. Experience during the two previous years had resulted in a greater selectivity of methods to save time and materials. In addition, the need for labor conservation became more acute in most areas as the war progressed. Of the 214,666 acres treated with Paris green and oil during the fiscal year ending 30 June 1945, approximately one-third of the applications were made with power equipment, including airplanes.

Until the days of DDT and the other residual insecticides, drainage was generally considered the most satisfactory means of achieving permanent malaria control. However, in an emergency program such as the Malaria Control in War Areas, geared to wartime tempo and urgency and carried on for the most part around temporary

the framework of its Malaria Control Drainage Program. A letter from the President to the Federal Works Administrator dated 4 December 1942, authorized the liquidation of the Work Projects Administration.[121] Certain of the projects survived through April 1943, and some Work Projects Administration labor was still available to the end of fiscal year 1943. The few drainage projects not on military property begun by that organization and still incomplete at its demise were taken over by the Malaria Control in War Areas if these could be approved within existing policy.[122]

In fiscal year 1943, 68 major drainage projects were operated in 13 States and Puerto Rico; 966,281 feet (183 miles) of

new ditches were constructed, 75.9 per cent by hand, 19.5 per cent with dynamite, and 4.6 per cent with machines.[123] A total of 1,257,104 man-hours of labor were expended on the various aspects of drainage works. During the winter of 1943-44, a maximum of 63 major drainage projects were in operation in 46 areas of 13 States and Puerto Rico.[124] Since a majority of the malaria mosquitoes in the continental United States do not fly more than one mile, drainage was usually concentrated within a one-mile radius of war areas. Where excessive breeding did not occur between the one-half mile and one mile radius, control of this area by larviciding was generally sufficient. In a few instances, it was necessary to install drainage works past the one-mile radius in order to obtain satisfactory

outlets.

Although nearly all the drainage work originally proposed for the older military establishments had been completed by the middle of fiscal year 1944, many new areas were being added, mostly prisoner-of-war camps and military hospitals. Major drainage was seldom justifiable around prisoner-of-war branch camps because of their temporary nature. However, larvicidal work was supplemented by drainage at some of the more nearly permanent base camps. In most instances, plain earth ditches were dug, without lining, sodding, erosion control, or appurtenant structures. The average cost for this type of excavation with hand labor was $1.46 per cubic yard. A total of 1,059 miles of this type of hand ditching was completed by 30 June 1944, involving over 600,000 cubic yards of excavation.[125]

Drainage activities on the Malaria Control in War Areas program continued on a gradually decreasing scale during 1945. This included machine and dynamite excavations, filling, installation of permanent ditch lining, ditch stabilization, cross-drain, and outlet construction. At the close of the fiscal year, little major drainage remained to be done since in most established areas it had been completed, since military bases were being inactivated, and since most States were no longer expanding antimalarial activities.[126]

Extramilitary permanent ditch lining was limited in the United States to a few situations where materials were furnished by property owners or local governments. The use of lining was more extensive in Puerto Rico where malaria mosquito production was more difficult to control and where the malaria hazard was greater; but even there, installation of Malaria Control in War Areas-produced ditch lining was confined to the vicinity of permanent military establishments.[127]

Special types of drainage structures were used where they offered the best solution to the control problem. At Jackson Barracks, Louisiana, a levee and a manually-operated flood gate were constructed. At Macon, Georgia, and in Puerto Rico, pumps were used for drainage. An inverted siphon was installed at Macon, Georgia. Hydraulic dredging was utilized effectively at Leesburg, Florida, and Macon, Georgia, and vertical drainage at Jefferson Barracks, Missouri.[128]

In addition to these larviciding and drainage operations, which comprised the principal malaria control activities of the Malaria Control in War Areas, filling was used to a limited degree. This was done by bulldozer, by diversion of streams, by sanitary landfill, and by dragline.[129]

To determine the extent of mosquito breeding and the amount eliminated by drainage, a census of 120,646 acres of watered

area was conducted during the winter of 1944 throughout the control zone.[130] Fifty-two per cent of these wet acres were classified as permanent problems, 28 per cent as semi-permanent, and 20 per cent as temporary. In addition to the above, 55 million linear feet of water-holding ditches, canals, and other watercourses less than ten feet in width were reported. More than one-third of each class of watered area (42,177 acres plus 25 million linear feet of ditches) was found to be breeding malaria mosquitoes, probably representing the significant acreage from the standpoint of Malaria Control in War Areas. It was further reported that 15,000 acres and 680 thousand linear feet of watered area were eliminated by drainage during the course of Malaria Control in War Areas operations.

The need for a shift in emphasis of Malaria Control in War Areas activities became apparent in 1943 with the arrival in this country of malaria cases from overseas. These included hospitalized, sick, or wounded servicemen, prisoners-of-war sent to the United States, and furloughed or discharged veterans returning to their homes in all of the 48 States. It was suspected - and later proved[131] - that malaria transmission could take place from these carriers in areas where domestic mosquito vectors existed. This led to the conviction that a major public health problem would ensue[132] - one which would increase with demobilization.[133]

Thus, in 1944 it was proposed to extend the Malaria Control in War Areas program to protect all previously endemic civilian areas in addition to those adjacent to strategic installations.[134]

By this time, the antimalarial effectiveness and low cost of residual insecticiding with DDT had been amply demonstrated by its military use in the tropics. The proposal, therefore, called for residual spray treatment with DDT in rural areas as a major operation and for some larviciding and drainage around urban locations. Work was to begin on 1 January 1945 in the most malarious counties in the southeast.

This proposed Extended Malaria Control Program of the Malaria Control in War Areas was endorsed by the Association of State and Territorial Health Officers in October 1944, with the recommendation that the Surgeon General of the U. S. Public Health Service present the program to the Congress;[135] military authorities approved the proposal.[136] The initial appropriation for the Extended Program was included in the First Supplemental Appropriation Act, October 1944, and was approved December 1944.[137]

The administrative pattern of the Extended Program was similar to that of other Malaria Control in War Areas activities, but the underlying philosophies governing the two were quite different. The regular Malaria Control in War Areas program was designed to protect military and war industrial personnel from civil-

ian malaria. The Extended Program, on the other hand, was primarily intended to protect general civilian populations from returning military carriers of the disease. Therefore, increased emphasis was placed upon participation by State and local health agencies.

The county was the usual unit of operation in the Extended Program and most projects were county-wide, excluding communities of 2,500 or more. Those in which residual spray treatment was to be carried out were selected on the basis (1) of average annual reported malaria death rates of 10 or more per 100,000 during the pre-war years 1938-42, inclusive; and (2) of supplemental information from the malariologists of the various State health departments as to the distribution of the disease in their own States.[136] From these data, 68 counties in 9 States were approved in 1945 for participation in the residual spray program.

Consideration was given to the possible requirements of five other States in the traditionally malarious belt where malaria had been transmitted with sporadic frequency. It was believed at first that the needs of these States might be met by the use of mobile units, but further analysis indicated that better and more permanent results would be achieved by establishing local projects under trained personnel in these areas.

During the 1945 season, 644,000 spray applications were

made in about 400,000 homes. In fiscal year 1946, the number of counties included in the Extended Program increased to 274, involving 1,025,361 homes.[139]

Larvicidal and minor drainage projects were undertaken in the Extended Program around urban areas wherever the annual cost of larviciding was lower than, or did not greatly exceed, the cost of residual spraying. Reconnaissance surveys or experience in previous project operations were used to determine these comparative costs. For each population group, either anti-larval or anti-adult measures were used, not both. In general, larviciding and minor drainage were the methods used for urban populations. A few major drainage projects were proposed under the Extended Program and submitted for approval as prescribed for regular Malaria Control in War Areas activities. Residual spray project proposals were prepared by the State health departments for each operational area where such work was contemplated. These were then reviewed by the Headquarters office before work was inaugurated.

Only a fraction of the total number of homes was sprayed before the end of fiscal year 1945.[140] Spraying began in most States during March and all but one State had started by the middle of April. Because of the delay in supplying equipment and materials to meet the essential requirements in all States, only 264,482 houses had been sprayed by the end of the fiscal year.

square foot for the average size home (see Fig. 9). In 1945, two seasonal applications of DDT were applied at the rate of 100 mg. per square foot. However, evaluation data indicated that a single seasonal application of 200 mg. per square foot would be equally effective from the standpoint of long-lasting residual and at the same time would be more economical. Consequently, from 1946 this rate was used in nearly all the States.

INSERT FIG. 9 NEAR HERE

A major problem involved in Extended Program operations was to obtain proper equipment in time and in sufficient quantity to meet project requirements.[142] Procurement, specifications,

During the last half of 1945, 413,500 houses in 123 counties were sprayed with DDT. This program was expanded in 1946 to operate in 274 counties in 13 States, accomplishing 611,881 house spray applications.[141] With the experience gained from one year's operation and the increased development of equipment and materials, the average man-hours required for residual spraying were reduced from 1.15 man-hours per house application at the beginning of the 1945 spraying season to 0.96 man-hour at the end of the year. The rate of DDT application varied from State to State, but the program average was 0.68 pound per house, or approximately 135 mg. per

testing, and modifications of equipment were joint responsibilities of the Engineering Division, the Equipment Unit, and the Carter Laboratory at Savannah. Numerous types of sprayers, spray nozzles, gaskets, hose, solvents, emulsifiers, and other items incidental to DDT residual spraying were tested. Procurement of xylene-resistant gasket and hose material was the most serious difficulty. Of the variety of gasket materials tested, only two were found satisfactory for field use. Three kinds of synthetic rubber hose proved usable. After testing and selecting suitable materials, further delay was experienced in furnishing such large supplies of specialized equipment, due to the failure of various manufacturers to meet delivery schedules. Most of the difficulties were finally overcome so that field crews eventually received all essential equipment.

Residual spraying with DDT was an entirely new method of malaria control for civilian purposes. Field testing had been limited to projects in Arkansas, Tennessee, Georgia, and Puerto Rico.[143] With only a handful of trained men and the most critical transportation situation in the history of our country, an extensive decentralized training program was set up, starting with a basic course at the Carter Laboratory at Savannah. This was designed for District and State supervisory personnel and was conducted as a series of discussions and field demonstrations. As a result of this course, the nucleus of trained men was increased

from a dozen to over 75 and each Extended Program State had at least two men with first-hand knowledge of the subject. Decentralized training within States was then inaugurated. Each one arranged for a training course for area supervisors and others charged with immediate responsibility for doing the work. Two mobile training units were equipped with literature, training aids, and equipment and were made available to the States. An officer with first-hand experience in DDT residual spraying was available to all States that requested assistance in conducting their in-service training programs.

Results of the DDT training program can be measured only in terms of smooth working operations. The fact that 1,200 men were put in the field within two months and carried on the program without any evidence of occupational hazards, major public complaints, or operational failure testifies to the effectiveness of the job.

Because of the low malaria rates prevailing at the time and the errors of available methods of measurement during the low ebb of the disease, the effectiveness of the residual spray program was determined entomologically, i.e., on the basis of its ability to maintain houses free of A. quadrimaculatus.[14] Random inspections of a number of premises on each control project were made at monthly intervals after the start of spraying to determine if any

TABLE 4.--Summary of Entomologic Surveys on the Extended (Residual Spray) Program

Months after spraying	Number of houses inspected			Percentage of houses free of *A. quad.* in p.m.		
	1945	1946	Total	1945	1946	Avg. 1945-46
Sprayed Houses						
0 - 1	3,916	6,018	9,934	98.9	99.2	99.1
1 - 2	4,558	6,739	11,297	98.3	99.0	98.7
2 - 3	3,557	5,321	8,878	95.7	99.1	97.7
3 - 4	1,375	2,974	4,349	94.7	98.7	97.4
4 - 5	723	899	1,622	94.2	98.2	96.4
TOTALS	14,129	21,951	36,080	97.2	99.0	98.3
Unsprayed Houses						
	----	1,639	1,639	----	87.3	87.3

Source: Bradley, G. H., and Lyman, F. E.: Discussion of Five Years' Use of DDT Residuals against *Anopheles quadrimaculatus*, J. Nat. Mal. Soc. 9: 113-118, 1950.

eliminating malaria from the United States as an endemic disease. Thus, the National Malaria Eradication Program was commenced on 1 July 1947. This was an augmentation of the previous Extended Malaria Control efforts.[145] As the result of these measures and possibly other circumstances, cases of truly indigenous malaria became difficult or impossible to find in subsequent years.[146] These facts are noted here because it is believed important to record and emphasize this essential relationship, namely, that what started as a relatively modest extramilitary malaria control pro-

live anophelines were present. From 1946, the number found in unsprayed houses adjacent to the treated areas was also determined. The results of these surveys for 1945 and 1946 are summarized in Table 4. It is evident from these figures that effective control of malaria mosquitoes was achieved in counties operating under the Extended Malaria Control Program. The role of this program in maintaining the downward trend of malaria incidence in this country may never be known, but in combination with the Malaria Control in War Areas program it must have contributed significantly to the negligible level of malariousness in the continental United States during and after World War II.

During the immediate post-war years continental malaria rates declined still further and it was, therefore, proposed to capitalize on the existing situation by making a serious effort at

gram in 1942 eventuated in 1947 as the first national malaria eradication campaign of substantial dimensions. This directly related descendant of the combined War Areas Malaria Control Programs stimulated other malaria eradication activities in various parts of the world, and, therefore, was of international significance.

Related Activities

In addition to malaria, there were other insect-borne diseases which could occur within the continental United States and its territories and would become threats to the military effort if they reached epidemic proportions. Of these, yellow fever was considered the most dangerous. The last epidemic of this disease occurred in New Orleans in 1905;[147] but the vector, Aedes aegypti (see Fig. 10), was present along the coastal areas from Virginia to Texas. Furthermore, epidemics of dengue, an incapacitating disease also transmitted by this mosquito, had flared up periodically in South Carolina, Georgia, Florida, Alabama, Louisiana, Mississippi, and Texas.[148]

INSERT FIG. 10 NEAR HERE

In the years before World War II, a number of large South American cities had eradicated A. aegypti.[149] Millions of dollars had been spent on these projects. To protect this investment, Bolivia had proposed at the Eleventh Pan American Sanitary Conference in Rio de Janeiro in 1942 an A. aegypti eradication project to include all the Americas. With the outbreak of war came a tremendous increase in air travel and the very real danger of introducing yellow fever and dengue into military training areas in this country. There was also the possibility that South American health authorities might quarantine airplanes arriving from aegypti-infested cities in the United States which could have seriously impeded the United States defense effort. As a result of these two potentialities, the anti-A. aegypti program was instituted. This was a lesser activity of the Malaria Control in War Areas and was restricted accordingly in funds and manpower; thus, great emphasis was placed on education of the public to supplement control operations aimed at eliminating major breeding foci. Projects of varying dimensions were carried on in Norfolk and Portsmouth, Virginia; Charleston, South Carolina; Savannah, Georgia; Jacksonville, Key West, Miami, and Tampa, Florida; Mobile, Alabama; and Brownsville, Corpus Christi, Galveston, Hidalgo County, Houston, Laredo, and San Antonio, Texas. During the four war years, some 4,700,517 premises were inspected.[150]

The first of these projects was started at Key West on 1 June 1942 with the special objective of eradicating the vector species; in this respect, it differed from all other antiaedine programs undertaken by Malaria Control in War Areas.[151] Each room in every dwelling and business establishment was visited each week. All mother foci of aegypti breeding were systematically located and were visited and treated each week. Searches were continued for casual breeding containers such as tin cans, rubber tires, outdoor cooking utensils, etc. When breeding was discovered indoors, the entire premises were sprayed with pyrethrum aerosol. The original breeding index of 13.2 was reduced to less than one per cent with relative ease;[152] but, as it was necessary in 1944 to redistribute funds and manpower to give protection to more critical war areas, complete eradication was not achieved. In most other projects, the numbers of premises where aegypti breeding occurred were held at or below five per cent, a level which at that time was considered to be the threshold of sanitary importance. Mobile A. aegypti-control units operated in Savannah, Georgia, and New Orleans, Louisiana.[153] These served a double purpose; while they maintained control activities in these cities, they also were immediately available for dispatch should dengue or yellow fever be reported anywhere in the United States. To provide further controls in case of such eventualities, an epidemic plan was devel-

oped and stockpiles of yellow fever vaccine and of mosquito control materials and equipment were held in readiness at Headquarters in Atlanta.

Fortunately it was not necessary to use the epidemic plan in the continental United States, but a call did come from a location remote from the mobile units and stockpiles of equipment and supplies. Dengue was reported in Honolulu, Territory of Hawaii, on 24 July 1943 for the first time in 30 years.[154] This occasioned some alarm in Army circles both because of its sudden and unexplained appearance - which was finally traced as being probably due to an infected Army Air Force pilot who, during his own incubation period, had flown a plane from the Fiji Islands where a dengue outbreak was in progress - and because a general epidemic in this area was to be avoided at all costs during 1943 as the Islands were to be the staging area for critical campaigns destined to turn the tide of battle during the fall of 1943 and the spring of 1944. Dengue built up rapidly until it was necessary on 8 August to declare Waikiki, one of the world's great recreation centers for servicemen, "off limits" to military personnel.

When the first two cases were reported, the Territorial Board of Health took immediate action against the spread of the disease. Nine sanitary inspectors, supplemented by 24 new employees and five soldiers (supplied because of the military importance

of the disease) made routine exterior inspections of premises, eliminating mosquito breeding where possible and suggesting corrective measures to householders. An educational campaign was also carried on by press and radio, and printed instructions were distributed requesting residents to spray their homes with insecticide and to eliminate all water-holding containers. In spite of these precautions, the number of dengue cases increased, especially in the Waikiki area. During the latter part of August 1943, at the suggestion of the Surgeon, Central Pacific Area, U. S. Army, all houses in this section were sprayed with undiluted commercial insecticide using high-pressure chemical warfare decontamination sprayers. A request was made by the Territorial Board of Health for assistance from the U. S. Public Health Service,[155] and on or about 1 September 1943 an engineer officer and an entomologist officer from Malaria Control in War Areas, both experienced in *A. aegypti*-control activities, were sent to Honolulu. By that time, 148 cases had been reported. These were scattered throughout the city, thus precluding all hope of confining the epidemic to the Waikiki district and making city-wide coverage essential. Thirteen civilian employees together with a medical officer made available by the Army to do epidemiologic work[156] and 50 soldiers were added to the existing mosquito-control organization. Operations began on 15 September.[157] By the end of the fiscal year, 150 men were

duction in numbers of new cases. The outbreak reached its peak in October (see Chart 4), but by the end of June 1944 the attack rate had subsided to less than one case per week. No cases were reported during the last two months of 1944 and the first four months of 1945. The total number of civilian cases was 1,506,[160] of military personnel, 56.[161]

INSERT CHART 4 NEAR HERE

The Malaria Control in War Areas organization also undertook on a reimbursable basis the control of certain obnoxious in-

employed on aegypti control in Honolulu and 23½ elsewhere in the Islands; these included two sanitary companies provided by the Army. The city was divided into districts and zones of such size that one man could inspect the inside and outside of each of the premises in the zone within 10 days. Aedes control in the Hawaiian Islands involved two species, aegypti and albopictus,[158] both of which were involved in the transmission of dengue.[159] The inspection-correction-education method was used to reduce the breeding indices of these species in and around dwellings, while simultaneous high-pressure spraying with emulsified pyrethrum-kerosene mixtures was used to fog entire areas of high dengue prevalence. This treatment of the epidemic foci was followed by a sharp re-

sects for the Armed Forces when this could be done advantageously. In several instances, pest mosquito reduction projects were thus extended into civilian areas near military establishments to provide greater freedom from the continual annoyance of bloodsucking insects, with consequent improvement in the physical effectiveness of military inductees during their training experience. Similarly, the control of dog flies, Stomoxys calcitrans, on the north Florida beaches to protect Army Air Force personnel from the depredations of these vicious biters was undertaken jointly with the Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture.[162]

Evaluation of Malaria Control in War Areas Activities

As shown in Chart 1, the rates of reported civilian malaria morbidity and mortality continued to decline during the war years with no indication of an upswing due to cyclical manifestations. Probably many factors were involved in producing this result, but it seems clearly evident that among the major ones were the competent leadership in and conscientious workmanship of the Malaria Control in War Areas and the State health departments concerned.

The best measure of effectiveness for intra- and extra-

military malaria control efforts is displayed in Chart 5 which contrasts the continental Army malaria admission rates during the five-year periods commencing in 1917 and 1941, representative of World War I and World War II experience with this disease. This double histogram was developed early in World War II by Colonel William A. Hardenbergh, Sn. C., and was added to each year thereafter as additional data became available.[163] It shows real progress in malaria control accomplishment in the 24-year interval between the two World Wars.

INSERT CHART 5 NEAR HERE

CONCLUSIONS AND RECOMMENDATIONS

The conclusions reached from this account of malaria control activity within and near military areas in the continental United States is that a capable job was done both by the military personnel concerned with the former, and by the civilian organization developed for the latter. The joint objective of these two operations was to protect military trainees from malaria. Malaria morbidity was held to progressively and virtually unprecedentedly lower levels in this group during each succeeding year of World

War II. In addition, the achievements of the combined War Areas Malaria Control Programs contributed directly to malaria eradication efforts in this country and abroad. This experience proves the feasibility of cooperative and productive accomplishment by military and civilian health authorities.

Therefore, it is recommended that, should the need ever arise again, the Armed Forces and the U. S. Public Health Service, acting in behalf of the State health departments, should collaborate on essentially the same basis as they did in World War II.

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79. See footnote 46.

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85. See footnote 83, p. 6.

86. See footnote 84.

87. Malaria Control in War Areas: Field Bulletin, August-September, 1945, p. 11, Table II. On file, Library, Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

88. Malaria Control in War Areas: Annual Report, 1945-46, Atlanta, Georgia, Federal Security Agency, U. S. Public Health Service, [1946], p. iii. On file, Library, Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

89. Malaria Control in War Areas: Field Bulletin, January 1945, p. 2. On file, Library, Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

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91. Malaria Control in War Areas: Annual Report, 1942-43, Atlanta, Georgia, Federal Security Agency, U. S. Public Health Service, [1943], pp. 9-11 and 38-40. On file, Library, Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia. See also footnote 83, pp. 7-11.

92. Malaria Control in War Areas: Annual Report, 1944-45, Atlanta, Georgia, Federal Security Agency, U. S. Public Health Service, [1945], p. 8. On file, Library, Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

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94. See footnote 91, pp. 12-14 and 41-49.

95. See footnote 91, pp. 15-18.

96. See footnote 91, p. 45.

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99. See footnote 83, p. 55.

100. See footnote 92, p. 5.

101. Malaria Control in War Areas: Manual of Operations, 1942-43. On file, Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

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104. Malaria Control in War Areas: Manual of Operations, 1943- . On file, Library, Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

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110. See footnote 84.

111. See footnote 91, p. 52.

112. See footnote 83, p. 19.

113. See footnote 92, p. 10.

114. See footnote 88, p. 57.

115. See footnote 83, p. 19.

116. See footnote 91, pp. 53-54.

117. See footnote 83, p. 21.

118. See footnote 83, p. 19.

119. See footnote 92, p. 10.

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123. See footnote 91, p. 64.

124. See footnote 83, p. 23.

125. See footnote 83.

126. See footnote 92, p. 13.

127. See footnote 83, p. 24.

128. See footnote 83, p. 25.

129. See footnote 83, p. 26.

130. See footnote 92, p. 13.

131. See footnote 69.

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136. Editor: Please obtain from Historical Unit.

137. See footnote 89, p. 4.

138. See footnote 89, pp. 5-6.

139. See footnote 88, p. 12.

140. See footnote 92, p. 18.

141. See footnote 88, p. 12.

142. See footnote 92, p. 18.

143. See footnote 92, p. 20.

144. See footnote 92, p. 24.

145. See footnote 75.

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151. See footnote 91, pp. 73-74.

152. See footnote 92, p. 31.

153. See footnote 91, p. 77.

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159. See footnote 154.

160. See footnote 92, p. 33.

161. See footnote 156.

162. See footnotes 91, pp. 78-79; 83, p. 43.

163. See footnote 29.

LEGENDS FOR ILLUSTRATIONS

Chart 1. Malaria morbidity and mortality rates in all States reporting cases and deaths during 1920-1946 inclusive. Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

Map 1. Areas of the continental United States believed to be malarious in 1882, 1912, 1932, and 1934-5. See footnote 12 in text.

Fig. 1. Anopheles quadrimaculatus, the vector of malaria in the eastern and southern regions of the continental United States. Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

Fig. 2. Anopheles freeborni, the vector of malaria west of the Rocky Mountains in the continental United States. Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

Map 2. Geographic distribution of three species of anophelines associated with malaria transmission in the continental United States. See footnote 38 in text.

Map 3. Location of Army installations in the continental United States where mosquito control was carried out in 1941. See footnote 66 in text.

Fig. 3. Same area of Army installation before and after mosquito control drainage. U. S. Army Signal Corps, Washington, D. C.

Map 4. Location of Army installations in the continental

United States where mosquito control work was carried out in 1945. See footnote 66 in text.

Fig. 4. Knapsack type sprayer developed by the Corps of Engineers for applying insecticides for mosquito control, three gallon capacity, Corps of Engineers Specification No. T-2262B. See footnote 66 in text.

Fig. 5. Portable power sprayer, gasoline engine driven, skid mounted, for application of insecticides for mosquito control, Corps of Engineers Specification No. T-2118. See footnote 66 in text.

Fig. 6. Stearman biplane applying DDT to control anopheline over Stuttgart, Arkansas, Army Air Base. U. S. Department of Agriculture Miscellaneous Publication No. 606.

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Map 5. Geographic distribution and types of projects being carried on by Malaria Control in War Areas as of 1 July 1943. See footnote 91 in text.

Map 6. Geographic distribution and types of Malaria Control in War Areas control operations in 1945-46. See footnote 88 in text.

Fig. 8. Airplane application of larvicide over a water-chestnut infested area of the Potomac River. Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

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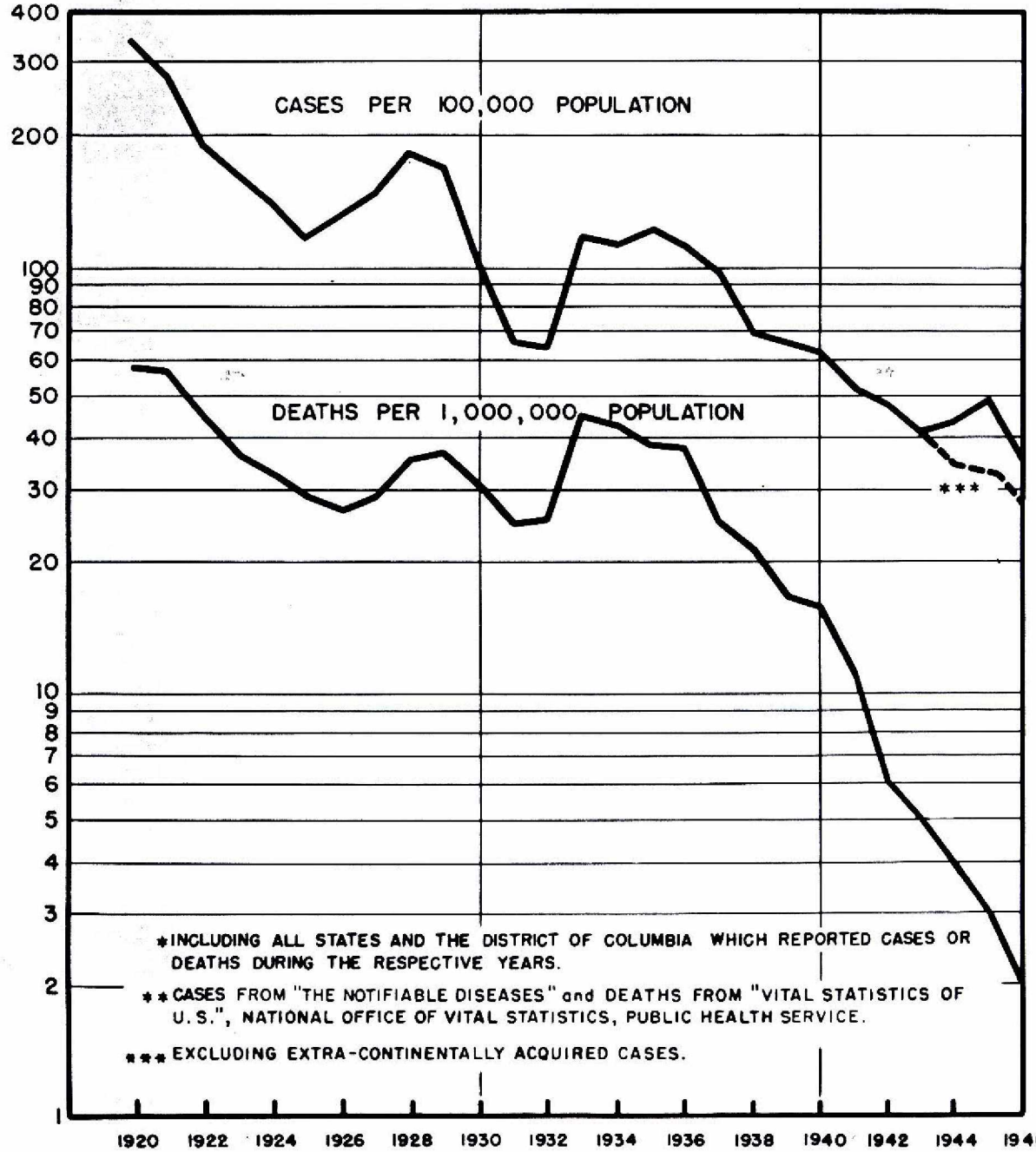
Chart 1. Malaria morbidity and mortality rates in all States reporting cases and deaths during 1920-1946, inclusive. Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

U. S. PUBLIC HEALTH SERVICE

COMMUNICABLE DISEASE CENTER

ATLANTA, GEORGIA

MALARIA MORBIDITY AND MORTALITY RATES IN ALL STATES* REPORTING CASES** AND DEATHS** DURING 1920-1946 INCLUSIVE



*INCLUDING ALL STATES AND THE DISTRICT OF COLUMBIA WHICH REPORTED CASES OR DEATHS DURING THE RESPECTIVE YEARS.

**CASES FROM "THE NOTIFIABLE DISEASES" and DEATHS FROM "VITAL STATISTICS OF U.S.", NATIONAL OFFICE OF VITAL STATISTICS, PUBLIC HEALTH SERVICE.

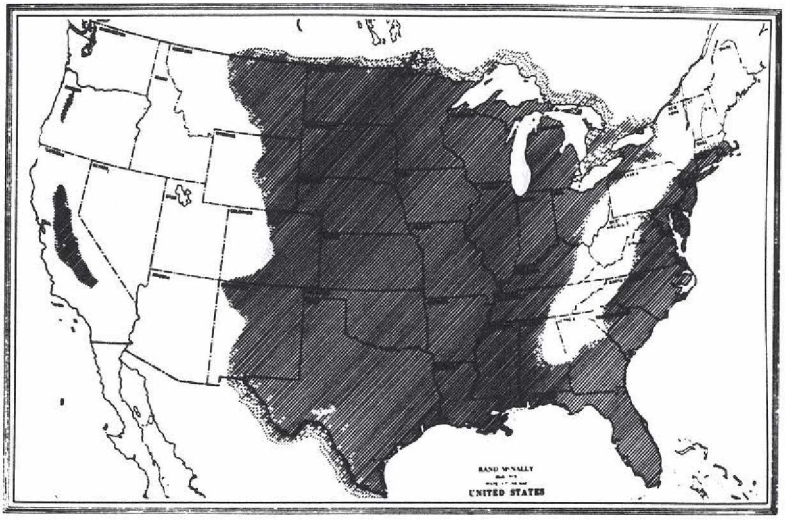
***EXCLUDING EXTRA-CONTINENTALLY ACQUIRED CASES.

DHEW-PHS-CDC ATLANTA, GA.

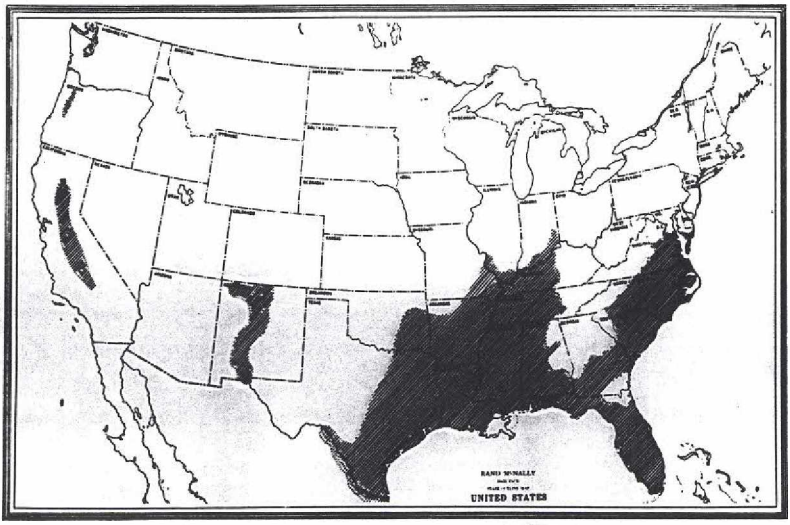
Rev. SEPT., 1954 AUG., 1947

Map 1. Areas of the continental United States believed to be malarious in 1882, 1912, 1932, and 1934-5. See footnote 12 in text.

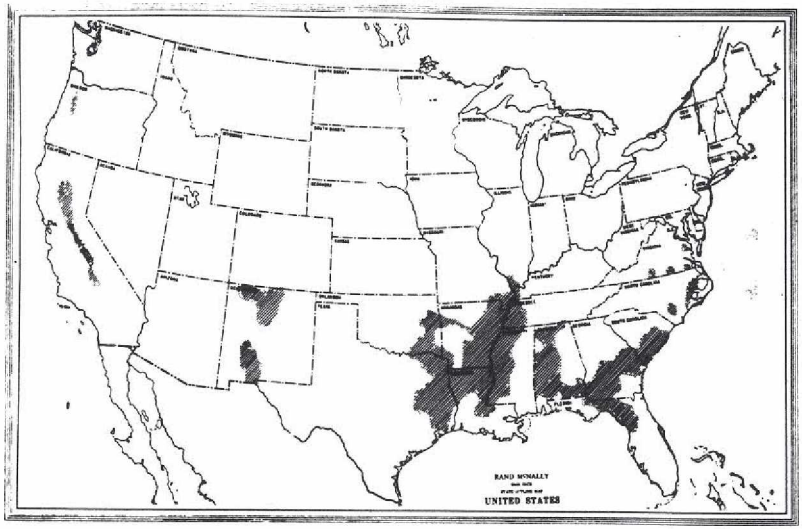
MALARIOUS AREA OF THE UNITED STATES
1882



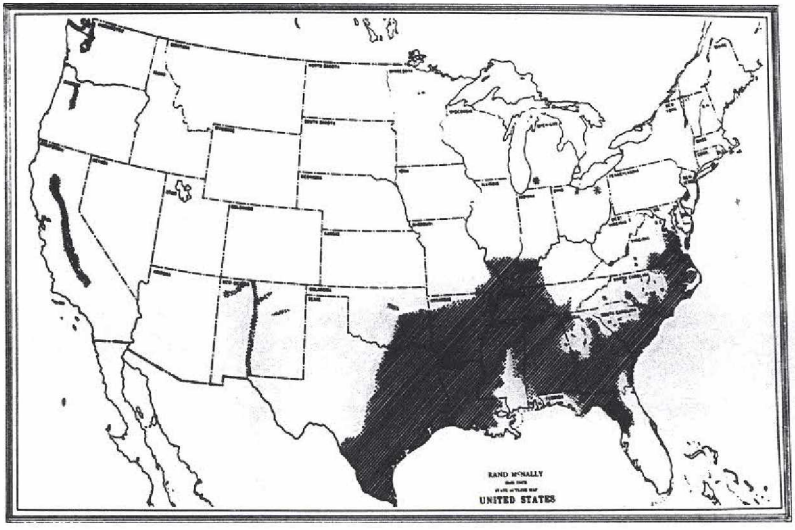
MALARIOUS AREA OF THE UNITED STATES
1912



MALARIOUS AREA OF THE UNITED STATES
1932



MALARIOUS AREA OF THE UNITED STATES
1934-5



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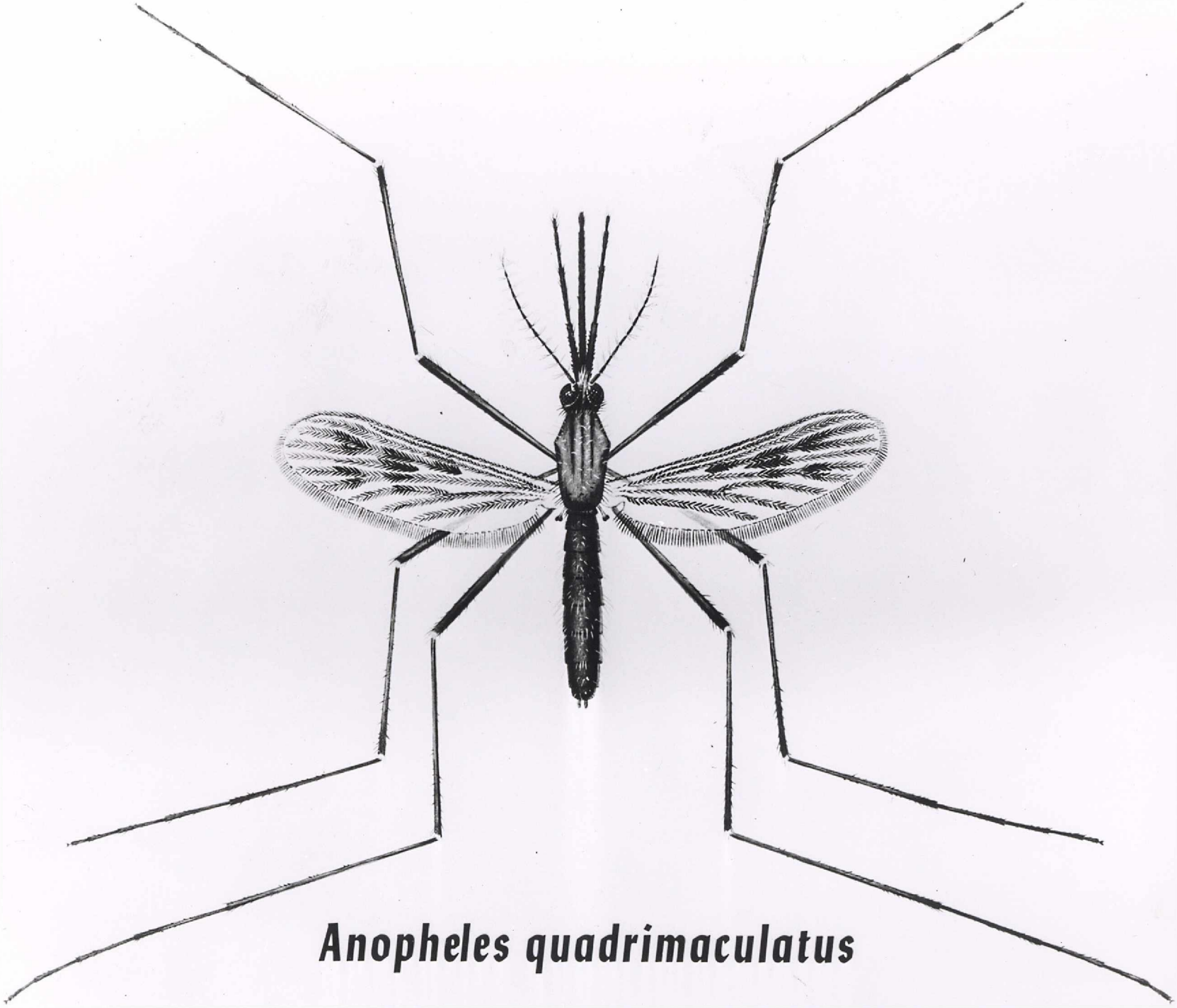
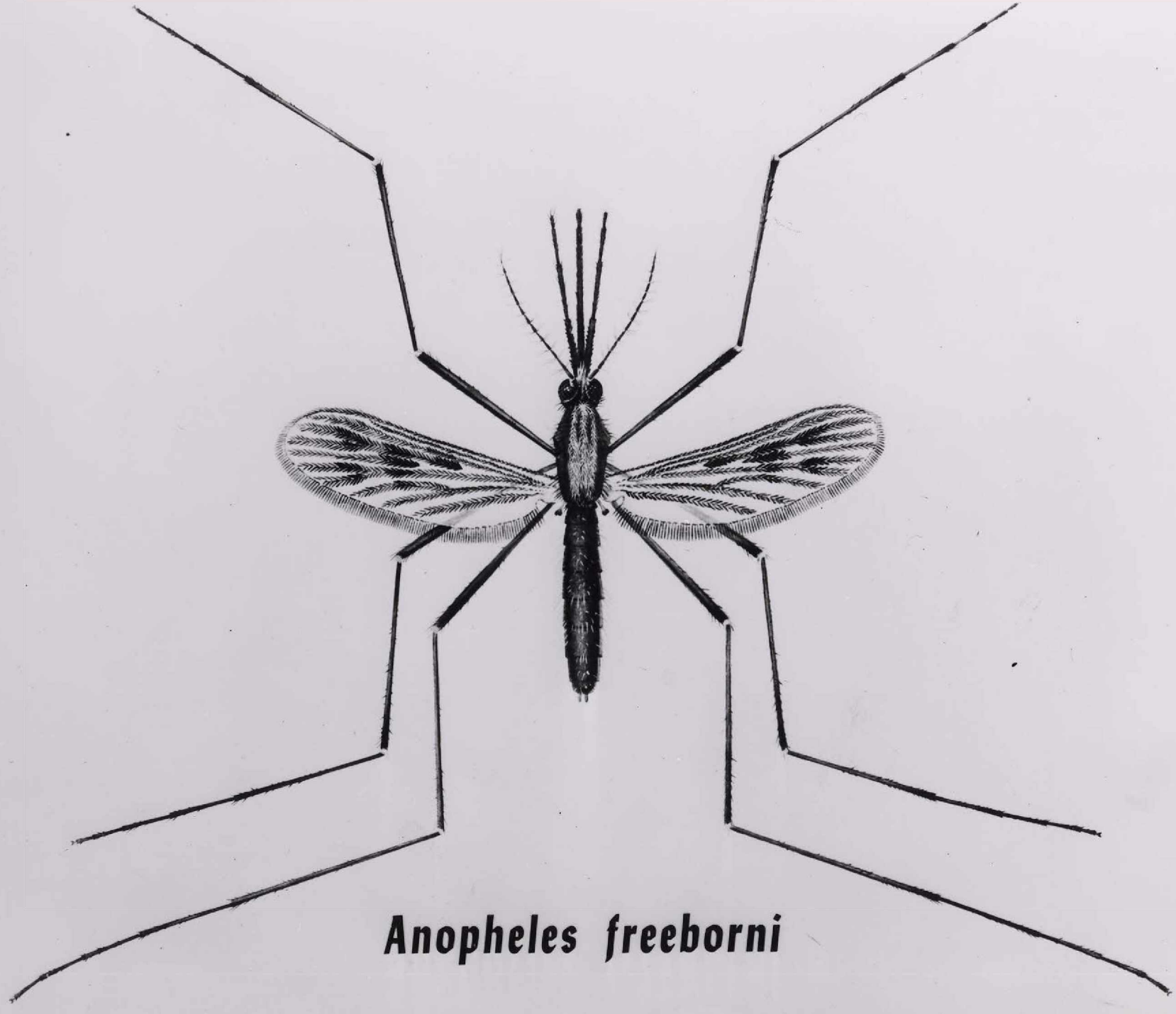


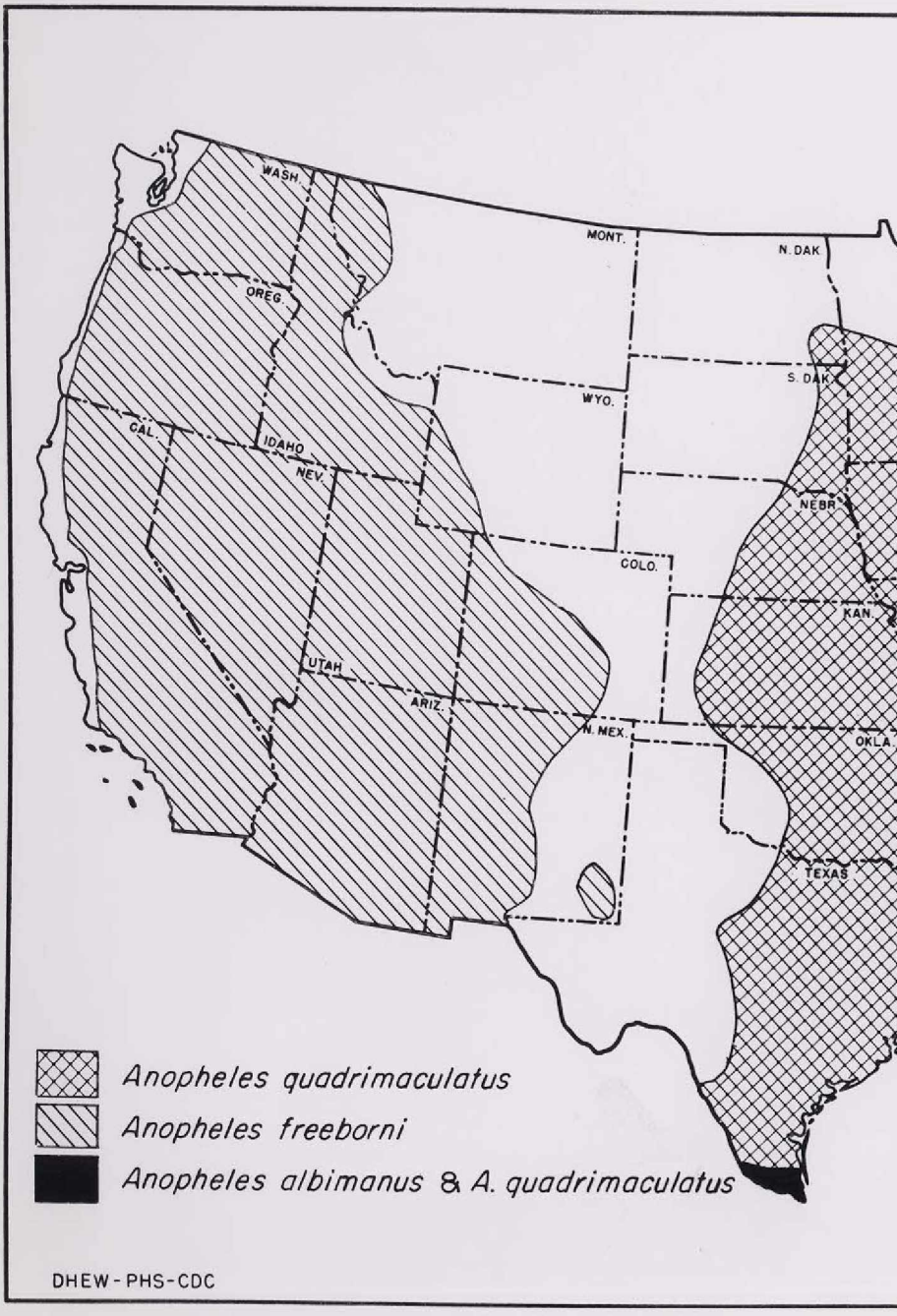
Anopheles quadrimaculatus

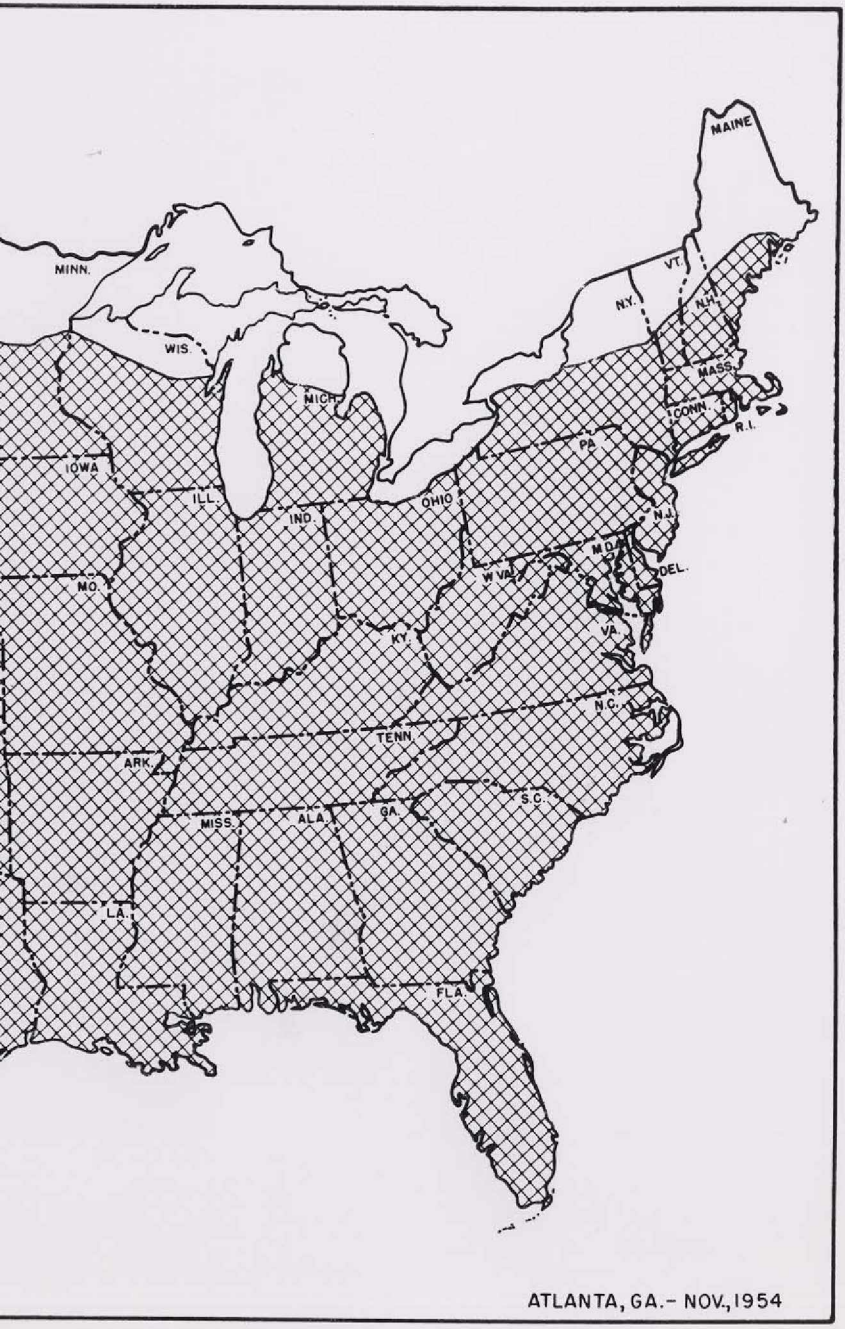
Fig. 2. *Anopheles freeborni*, the vector of malaria west of the Rocky Mountains in the continental United States. Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.



Anopheles freeborni

Map 2. Geographic distribution of three species of anophelines associated with malaria transmission in the continental United States. See footnote 38 in text.


WASH.
OREG.
CAL.
IDAHO
NEV.
UTAH
ARIZ.
MONT.
WYO.
COLO.
N. MEX.
N. DAK.
S. DAK.
NEBR.
KAN.
OKLA.
TEXAS
Anopheles quadrimaculatus
Anopheles freeborni
Anopheles albimanus & A. quadrimaculatus
DHEW - PHS - CDC



ATLANTA, GA.- NOV., 1954

Map 3. Location of Army installations in the continental United States where mosquito control was carried out in 1941. See footnote 66 in text.

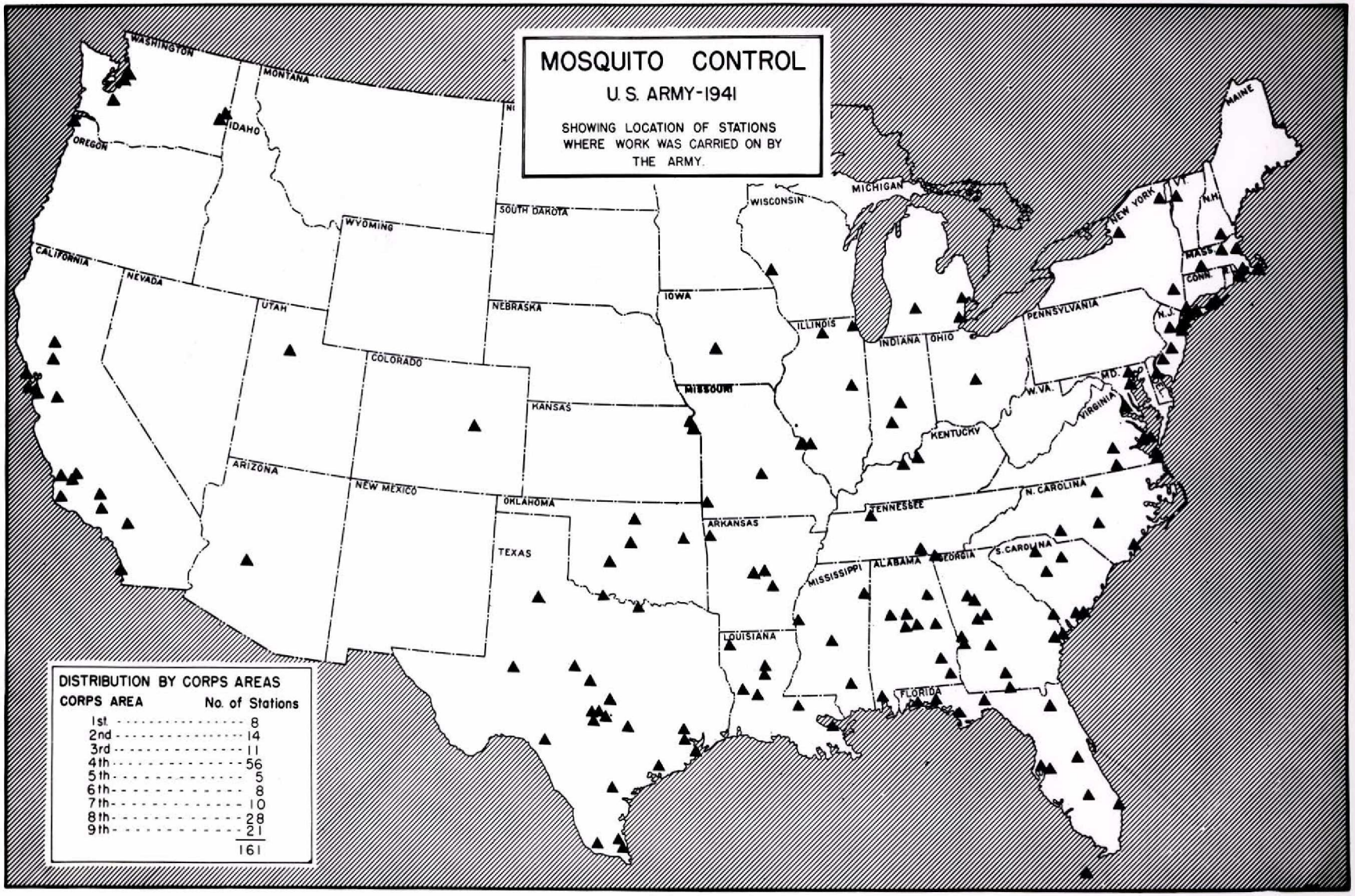

MOSQUITO CONTROL
U. S. ARMY-1941
SHOWING LOCATION OF STATIONS
WHERE WORK WAS CARRIED ON BY
THE ARMY.
WASHINGTON
MONTANA
IDAHO
OREGON
WYOMING
SOUTH DAKOTA
CALIFORNIA
NEVADA
UTAH
COLORADO
NEBRASKA
KANSAS
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
S. CAROLINA
N. CAROLINA
VIRGINIA
W. VA.
PENNSYLVANIA
NEW YORK
MD.
N.J.
CONN.
MASS.
VT.
N.H.
MAINE
DISTRIBUTION BY CORPS AREAS
CORPS AREA No. of Stations
1st ---------- 8
2nd ---------- 14
3rd ---------- 11
4th ---------- 56
5th ---------- 5
6th ---------- 8
7th ---------- 10
8th ---------- 28
9th ---------- 21
161

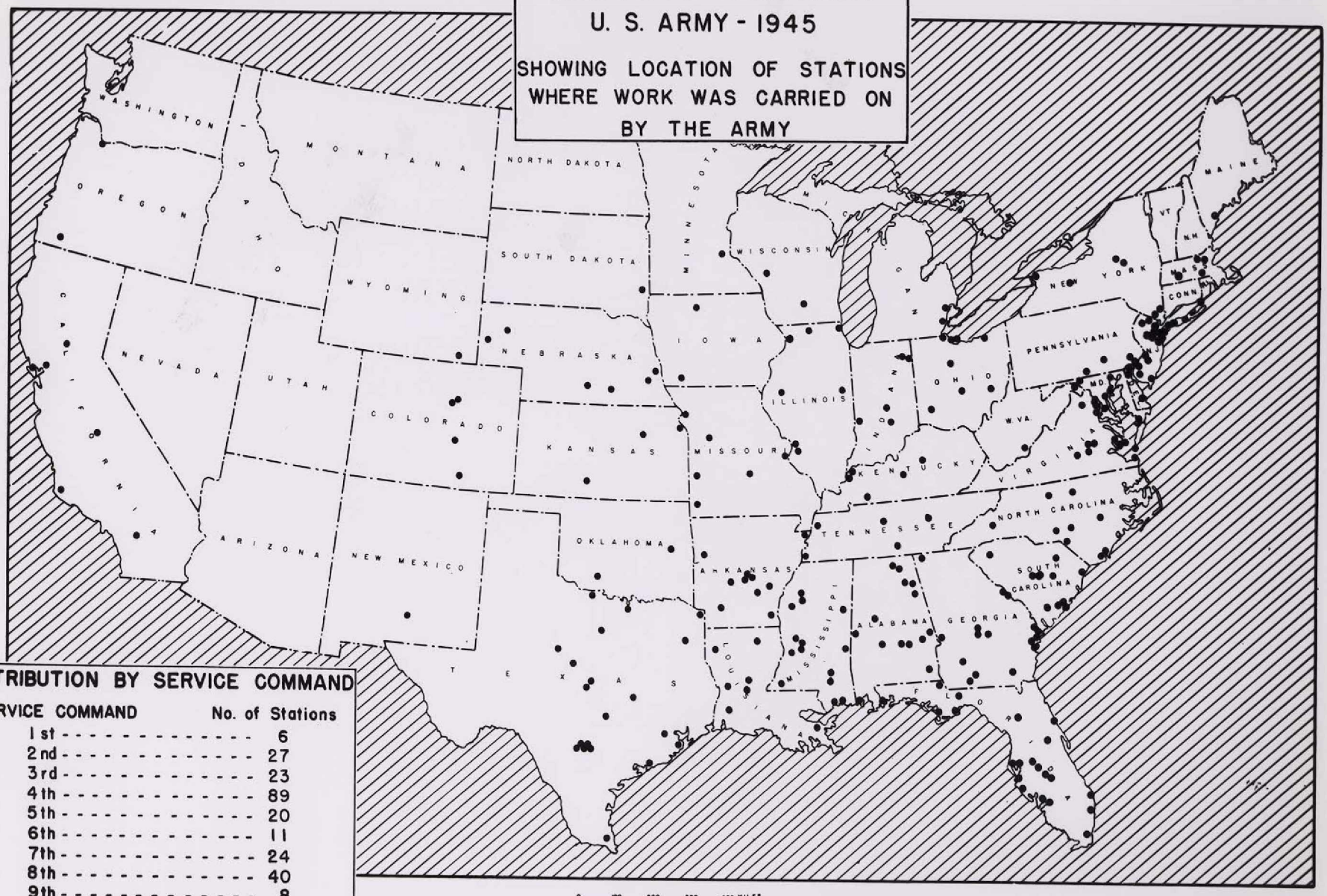
Fig. 3. Same area of Army installation before and after mosquito control drainage. U. S. Army Signal Corps, Washington, D. C.

Map 4. Location of Army installations in the continental United States where mosquito control work was carried out in 1945. See footnote 66 in text.

MOSQUITO CONTROL

U. S. ARMY - 1945

SHOWING LOCATION OF STATIONS WHERE WORK WAS CARRIED ON BY THE ARMY



DISTRIBUTION BY SERVICE COMMAND

SERVICE COMMAND	No. of Stations
1st	6
2nd	27
3rd	23
4th	89
5th	20
6th	11
7th	24
8th	40
9th	8
	248

109652

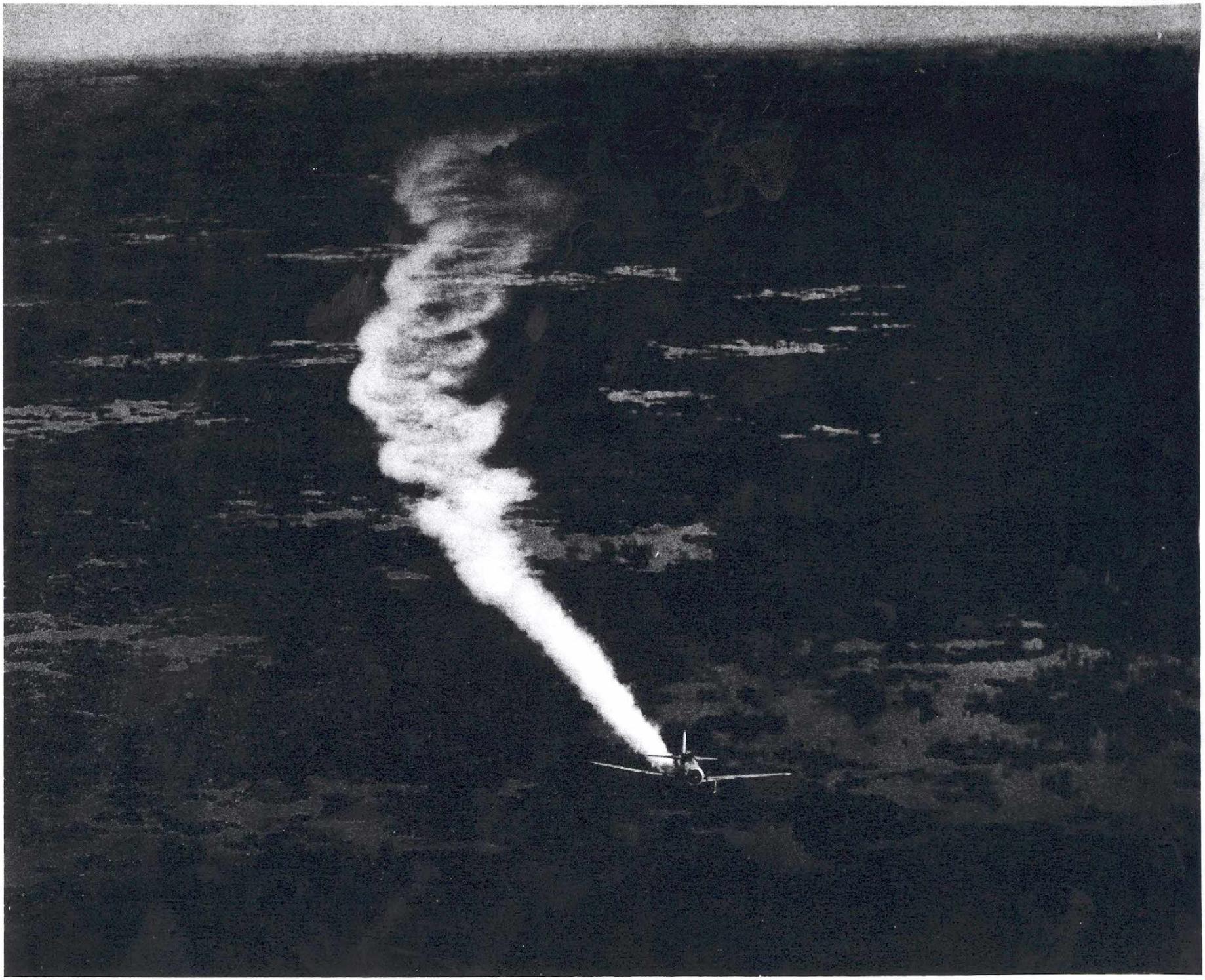
Fig. 4. Knapsack type sprayer developed by the Corps of Engineers for applying insecticides for mosquito control, three gallon capacity, Corps of Engineers Specification No. T-2252. See footnote 66 in text.

Fig. 5. Portable power sprayer, gasoline engine driven, skid mounted, for application of insecticides for mosquito control, Corps of Engineers Specification No. T-2118. See footnote 66 in text.

Fig. 6. Stearman biplane applying DDT to control anophelines over Stuttgart, Arkansas, Army Air Base. U. S. Department of Agriculture Miscellaneous Publication No. 606.

Fig. 7. Hand-spraying residual DDT in Army barracks. U. S. Department of Agriculture.

Fig. 8. Airplane application of larvicide over a water-chestnut infested area of the Potomac River. Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

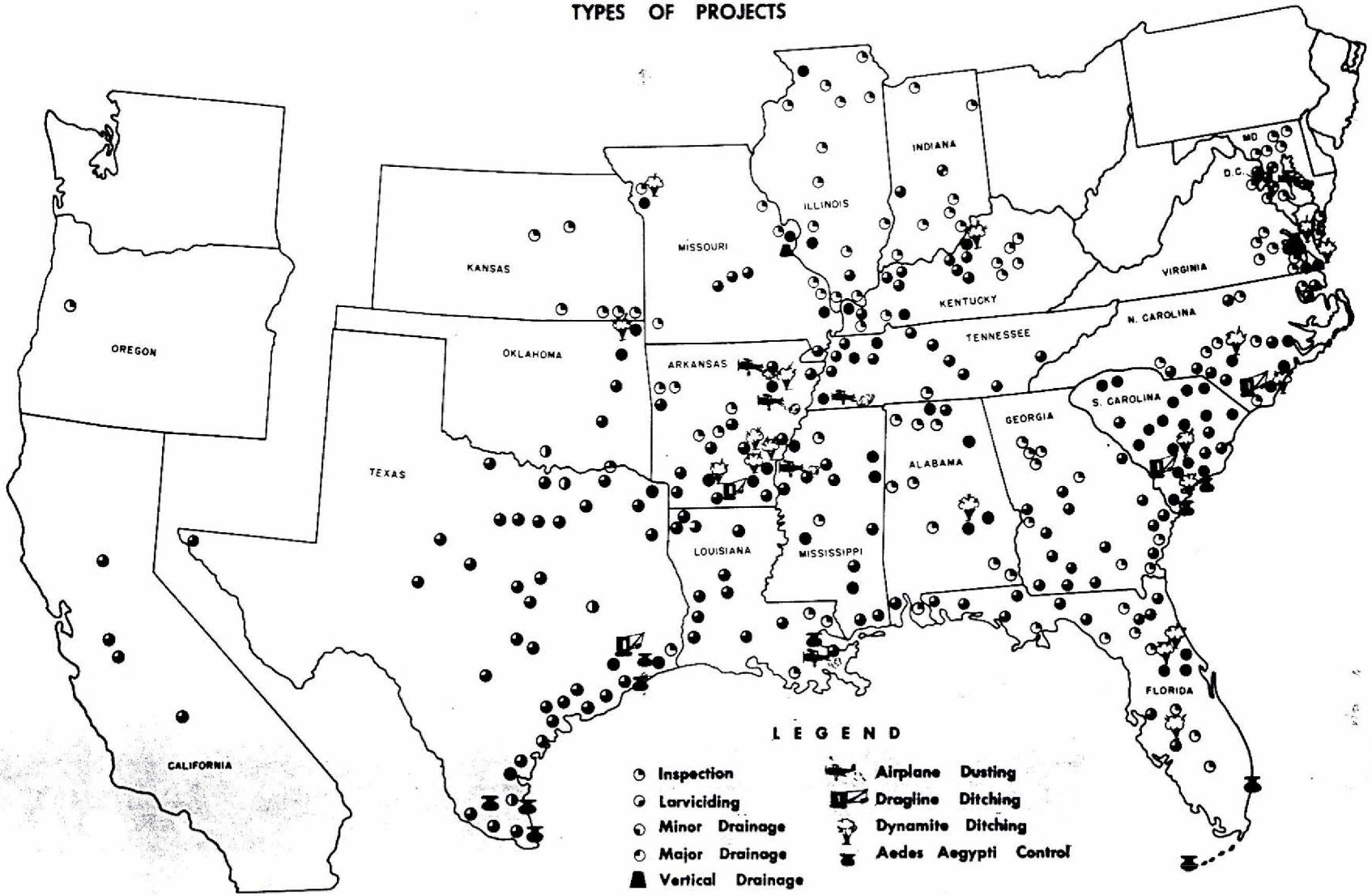


Map 5. Geographic distribution and types of projects being carried on by Malaria Control in War Areas as of 1 July 1943. See footnote 91 in text.

U. S. PUBLIC HEALTH SERVICE

MALARIA CONTROL IN WAR AREAS

TYPES OF PROJECTS



July 1, 1943

Chart 2. Malaria Control in War Areas, lines of authority and interrelations.
Malaria Control in War Areas Field Bulletin, September 1944.

MALARIA CONTROL IN WAR AREAS

LINES OF AUTHORITY AND INTERRELATIONS

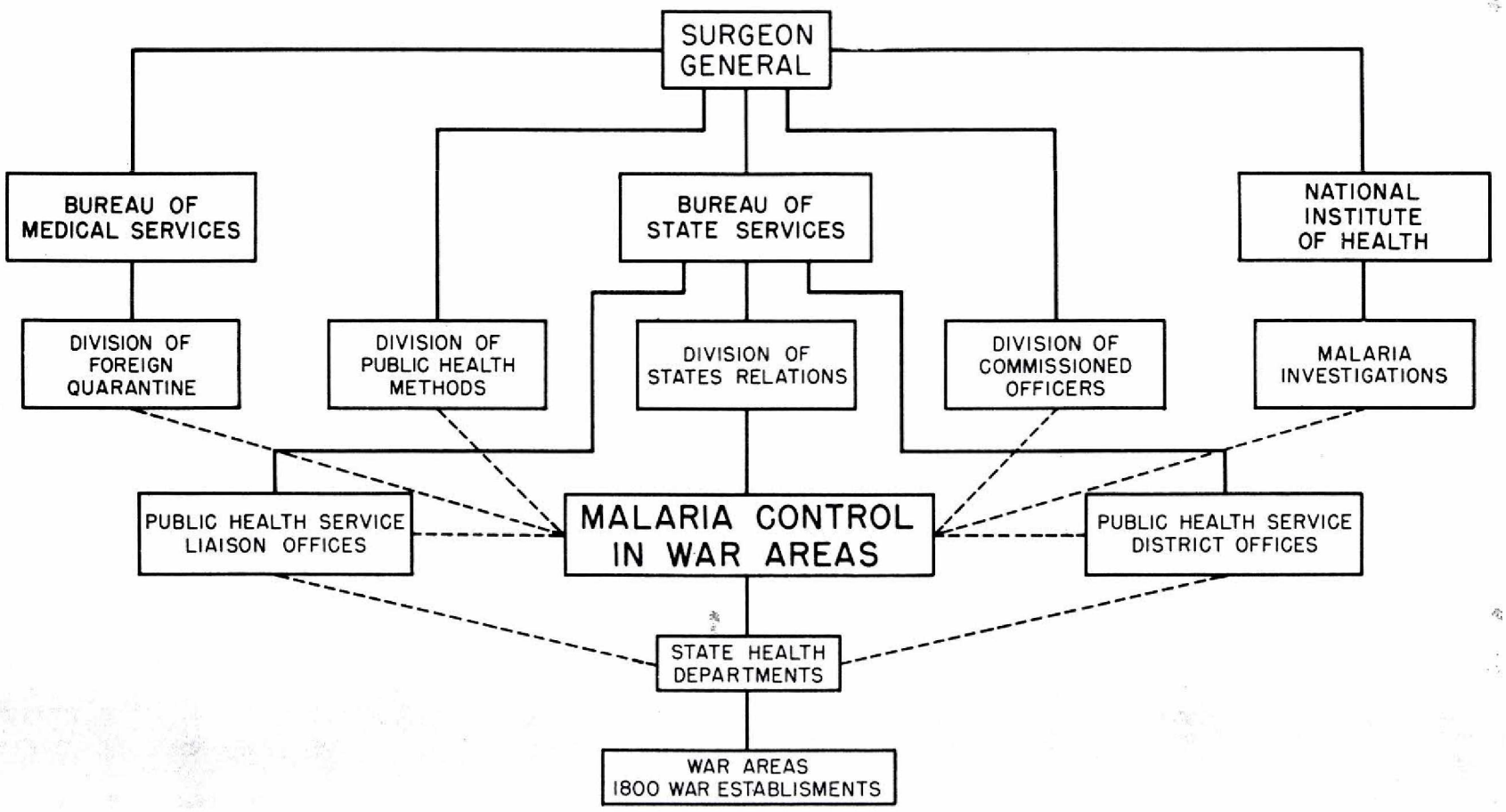
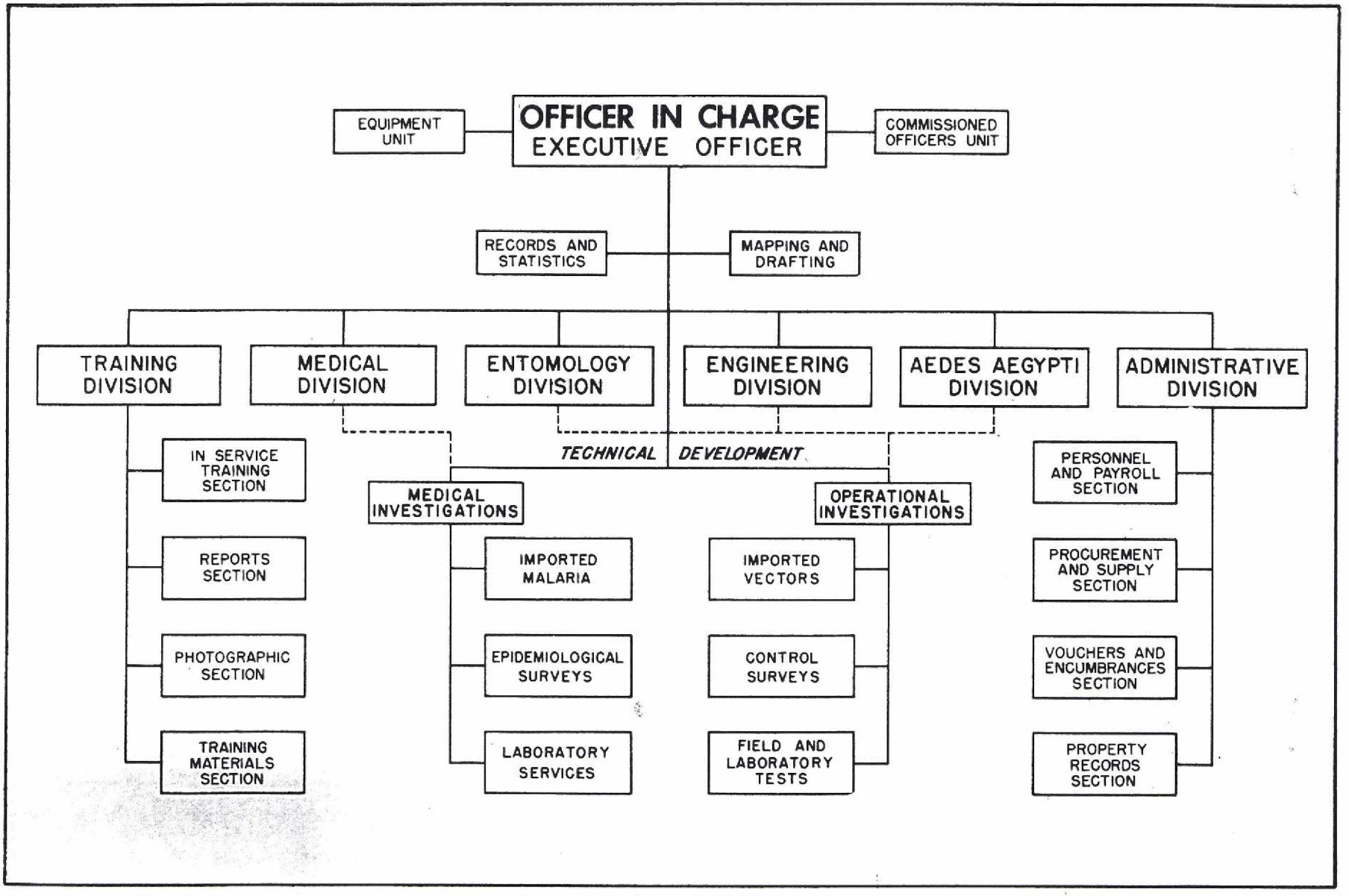


Chart 3. Headquarters organization of the Office of Malaria Control in War Areas. See footnote 83 in text.



Headquarters Organization of the Office of Malaria Control in War Areas

Map 6. Geographic distribution and types of Malaria Control in War Areas control operations in 1945-46. See footnote 88 in text.

WAR MALARIA CONTROL OPERATIONS

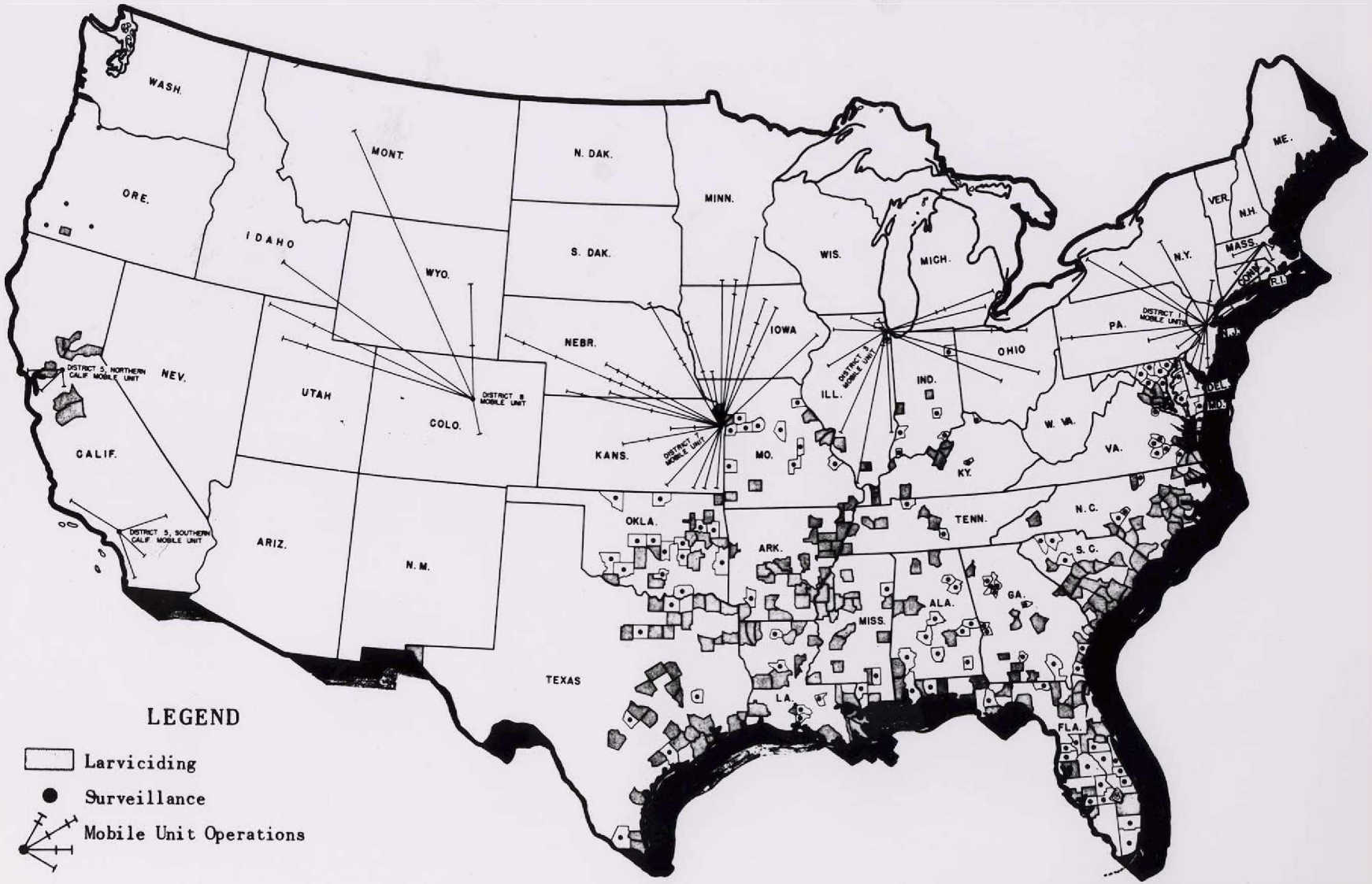


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Fig. 10. *Aedes aegypti*, the vector of yellow fever and dengue along the coastal areas of the continental United States from Virginia to Texas. Communicable Disease Center, U. S. Public Health Service, Atlanta, Georgia.

Aëdes aegypti

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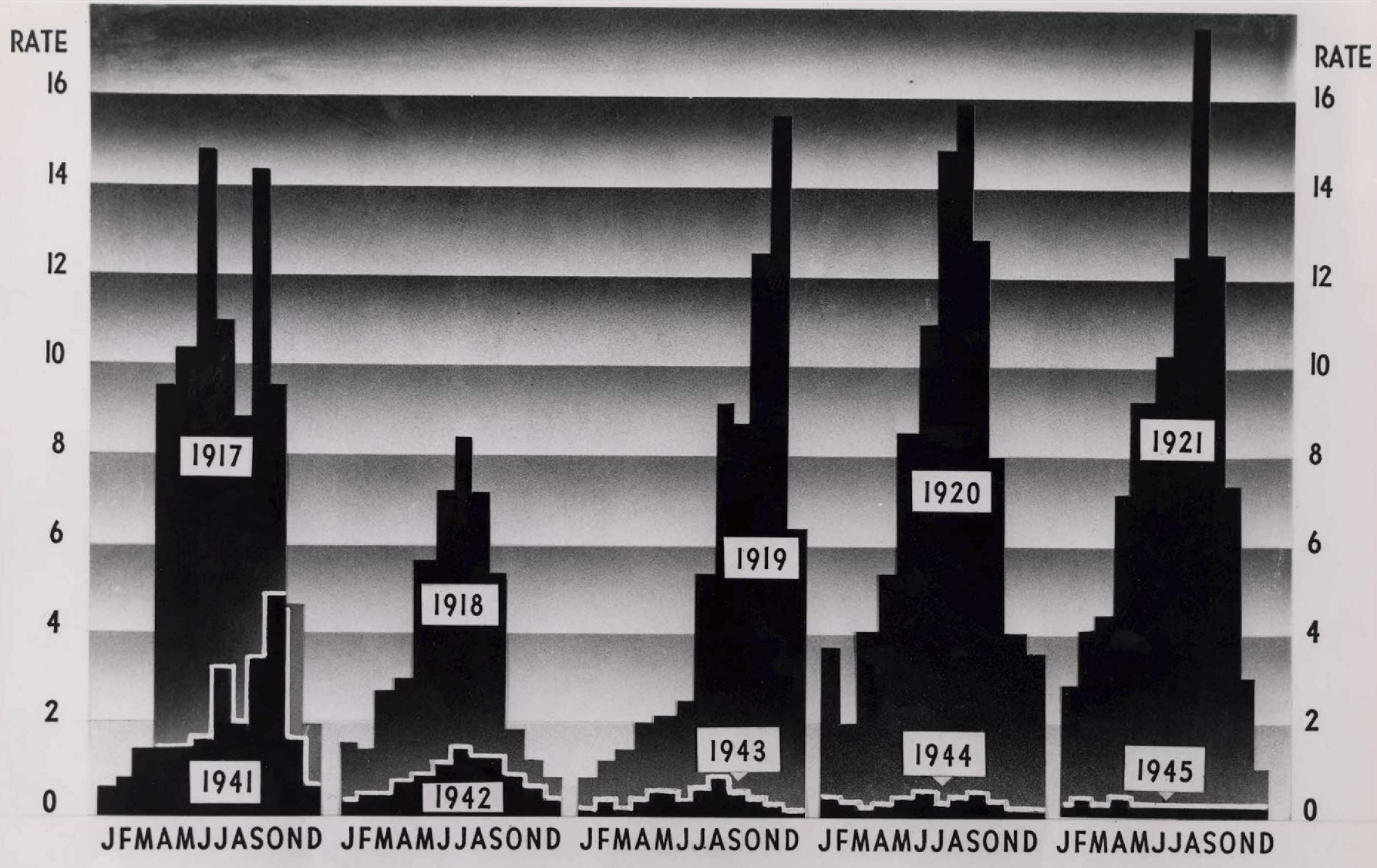

MALARIA ADMISSIONS PER THOUSAND MEN PER YEAR FOR THE ARMY IN THE CONTINENTAL UNITED STATES. WORLD WAR I- WORLD WAR II.

Chart 5. Malaria admissions per thousand men per year for the Army in the continental United States, World War I - World War II. See footnote 29 in text.

Chart 4. Trend of dengue cases compared with rainfall and the *Aedes* breeding index during the dengue epidemic in Honolulu, 1943-44. See footnote 83 in text.